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A STUDY OF THE RELATIONSHIP BETWEEN THE TENSION ("ISOMETRIC") PERIOD OF THE LEFT VENTRICLE AND PHYSICAL TRAINING IN YOUNG ADULT MEN

by

Gordon Edward Howard

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in the
University of Michigan
1968

Doctoral Committee:

Professor Henry J. Montoye, Chairman
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Associate Professor M. Anthony Schork
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A STUDY OF THE RELATIONSHIP BETWEEN THE TENSION ("ISOMETRIC") PERIOD OF THE LEFT VENTRICLE AND PHYSICAL TRAINING IN YOUNG ADULT MEN

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Chairman: Henry J. Montoye

The purpose of this study was to determine the magnitude of the diurnal variation of the tension period and the effects of a vigorous physical training program on the duration of the tension period. The tension period, as defined by Raab (2) is equal to the duration of left ventricular systole minus the duration of left ventricular ejection. The tension period is the sum of the latent period and the isometric period as defined by Wiggers (3).

Nine subjects participated in the diurnal variation study. The subjects reported for tension period measurement at four different times during the day. The first test was made with the subject in the post-absorptive state early in the morning. Subsequent tests were made before and after lunch and late in the afternoon. Least-squares analysis of variance revealed no significant differences between the variables of resting heart rate, total systole, ejection period and tension period between tests.

Fifty volunteer college men were divided into Experimental and Control groups. The Experimental group entered a five day a week, five week training period in which the average energy expenditure per daily training session was estimated at seven hundred and thirty Calories. Members of the Control group did not increase their daily physical activity during the first five week training period. At the end of the first training program the roles were reversed. The Experimental group became inactive while the Control group participated in a training program. The Experimental and Control subjects had their tension periods and fitness levels measured before the first training period, after the first training period and after the second training period. A group of fifteen athletes was tested once for comparison with the non-athletes. Fitness was measured by the Harvard Step Test (1).

Least-squares analysis of variance of the data showed that the Experimental group improved significantly in fitness between the first and second tests, and regressed significantly between the second and third tests. Tension period did not change significantly at any time. The Control group did not change significantly among tests. While the athletes were far superior in fitness to the non-athletes, there was no significant difference between the duration of the tension periods of the athletes and those of the non-athletes.

From these data it is concluded that the tension period of the left ventricle is not affected by normal daily activity, nor is it a valid measure of physical fitness.

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CHAPTER I

INTRODUCTION

The use of the left ventricular tension period as an index of human physical and cardiac condtion has been promoted by Dr. Wilhelm Raab for many years (40, 41, 42, 43). The evidence in support of this theory has been recently reviewed by Dr. Raab (41). The studies reviewed by Raab show that the tension period (TP), as measured by the method of Blumberger (7), increases in duration as the level of physical condition ("fitness") of the individual increases. On the basis of these findings, Raab has recommended that the tension period be measured as a part of regular medical examinations and in epidemiological studies (42).

The explanation of the tension period's changes in response to physical activity has not been clear or acceptable to several investigators. Consequently, additional studies have been conducted (12, 13, 36). These studies present data that conflict with the data presented by Raab (41). In particular, a study by Montoye and co-workers (36) showed no significant relationship between TP and physical activity as determined by the Reiff questionnaire (44). This particular study was part of the Tecumseh Community Health Study, an epidemiologic study of an entire community. A description of this study is given elsewhere

(35). The failure of Montoye's study to produce results comparable to those reported in the literature has prompted this study.

The cost of measuring TP in a study as large as the Tecumseh Study is prohibitive unless the measure is positively established as a valid and reproducible index of physical condition. The advantages of using TP as an index of physical condition lie in the fact that it is measured while the patient is at rest. It requires no exertion, as do other "fitness" tests. Consequently, the effects of age, health and motivation on the ability and desire to perform an exercise test are eliminated. Secondly, when used in conjunction with other measures taken during physical examinations, the measurement of TP may be taken at any convenient time during the examination without concern for the effects of exercise on subsequent tests.

The initial impetus for this study came from the conflicting results of a study by Montoye and associates (37) and those reported in the German literature reviewed by Raab (41) and conducted by Raab himself (40, 41, 42, 43). The measurement of the tension period has been taken in at least two large studies in the United States by investigators other than Raab and his associates. One of these studies, the Tecumseh Study (35), has been previously mentioned; the other is a longitudinal study of the faculty of the University of Michigan. Other studies of a similar magnitude may also be considering the use of this measurement. It is important, therefore, that the existence of a valid

and reproducible relationship between the tension period and cardiovascular fitness (physical condition) be established.

Secondly, there are several deficiencies in the experimental design of previous experiments. One of the common problems with previous studies is the lack of homogeneity of subjects in the control and experimental groups, particularly in relation to age. Several investigators have found a significant positive correlation between age and the duration of the tension period (28, 37). However, sample groups have been studied in which the subjects differ in age as much as thirty years or more (18, 26, 28, 31, 40, 42, 43). The effects of age variation between groups have not been taken into consideration in these studies.

A second problem concerns the use of control subjects. Previous studies have used controls in two ways. In one category of studies, comparisons were made between an athlete or "active" group and an "inactive" or normal group (15, 26, 31, 37, 40, 41, 42). In the second category, comparisons were made between the same subjects before and after a physical conditioning (training) program (40, 41). One study has used a control group and an experimental group that was tested before and after a training period (12). While the results of this study support Raab's conclusions, the study must be disqualified on the basis of a gross error in recording technique. This error will be discussed in the section concerning methodology. None of the studies to date have made comparisons between the duration of the

tension period of a control group, that of a training group before and after training, and that of an athlete group.

The studies listed above are lacking another important element. With the exception of the study by Coyne (12) no physical fitness, cardiorespiratory fitness or physical work capacity tests were administered to the various experimental, control, athlete and non-athlete groups to determine by some form of objective exercise test the fitness level of the persons in each group. Consequently, there are no data to show that the athlete group was, in fact, superior to the non-athlete group or that any physical conditioning occurred in training studies. Raab (40) apparently has used a decrease in resting heart rate as an indicator of improved physical condition.

The measurement of the tension period in an epidemiologic study almost precludes measurement in a basal state. Furthermore, in large studies it is difficult to allow more than fifteen to thirty minutes of rest prior to the taking of measures of TP and heart rate. Many of the subjects will not arrive for testing in the post-absorptive state, or even shortly after arising from bed. It is therefore important to know the magnitude of the diurnal variation brought about by the consumption of food and normal daily activities.

Frank and Kinlaw (18) have compared a basal and a non-basal group for differences in TP. None was found. Retests of the basal group after fifteen minute intervals and two week intervals were not significantly different. Similarly, the retest of the non-basal group

showed no significant change. None of the studies reviewed investigated the effects of meals on the duration of TP. Raab, however, has shown that caffeine and nicotine will shorten TP.

Purposes of the Study

The three purposes of this study were:

1. To determine the magnitude of the diurnal variation of the tension period during a twelve hour period;

2. To study the relationship of the duration of the tension period to the cardiovascular fitness level of homogeneous groups of highly trained male college athletes and untrained college men; and

3. To study the effects of a five week rigorous training period on the duration of the tension period in a group of non-athletic college men.

CHAPTER II

METHODOLOGY: DIURNAL VARIATION STUDY

Subjects

The subjects were nine graduate students at the University of Michigan, ranging in age from twenty-two to thirty-three years. Each subject was asked to report for examination four times during the day. The first test (T-1) was given in the early morning while the subject was in the post-absorptive state. The subsequent examinations were made approximately one hour before and after lunch and in the late afternoon. Due to limitations in the availability of testing facilities, these tests were carried out on Saturdays and Sundays. The nine subjects were tested over a two-month period with each subject completing his tests during one day.

Variables Studied

The following variables were measured at each test:

Resting Heart Rate (HR): The subject's heart rate while resting quietly in a supine position.

Total Systole (TS): The duration of left ventricular contraction.

Ejection Period (EP): The duration of left ventricular ejection of blood.

Tension Period (TP): The sum of the duration of the latent period and isometric period as defined by Wiggers (55, 56).

Q-Q Interval: The time between the onset of one Q wave (or R wave if the Q wave is not present) and the next Q wave in an electrocardiogram.

Instrumentation

Electrocardiograph: An Electronics for Medicine eight channel oscillograph was used as the recording instrument for the electrocardiograms, phonocardiograms, carotid pulse and respiration. All resting measures were recorded at a paper speed of one hundred millimeters per second with time lines spaced at two-hundredths of a second intervals (two milimeters apart). Figure 2-1 is an example of the type of tracings obtained. The tracings were made on photosensitive paper and developed under standard darkroom procedures. Accuracy of the spacing of the time lines was determined by recording the vibrations of a C-128 tuning fork with the aid of a piezoelectric transducer. The time lines were judged accurate. Exercise and recovery heart rates were recorded at a paper speed of ten millimeters per second with time lines one second apart. Accuracy of the paper speed was determined on each tracing by measuring the distance between fifty time lines.

Carotid Pulse Transducer: A Statham P23Db pressure transducer was used to detect the indirect carotid pulse. The pressure chamber was connected to a stethoscope bell by a piece of rubber tubing approximately six inches long. The bell was held to the neck over the pulse so that an air-tight seal was formed. The deflections of the skin as the pulse wave passed underneath changed the pressure in the chamber.

The transducer was attached to a strain gauge amplifier in the oscillograph.

Respiration Transducer: A Sanborn Model 374 pressure transducer was used to record respiration. Pressure changes in a child's blood pressure cuff placed around the subject's lower chest or abdomen were recorded in the same manner as the carotid pulse. The transducer was connected to a standard electrocardiograph amplifier in the oscillograph.

Phonocardiogram Microphone: A Cambridge crystal microphone (PM5TC) was used to pick up the heart sounds. It was connected to one of the multipurpose amplifiers of the oscillograph.

Test Procedure

Each subject was tested four times during the same day. Test One was administered in the post-absorptive state at about seven o'clock in the morning. After Test One, the subject was allowed to eat his regular meals with the exception of foods containing caffeine or other stimulants. Smoking was prohibited for the day and physical activity was kept to a minimum.

The typical testing procedure was:

1. The subject entered the laboratory and removed his shoes and shirt.

2. The subject's name and age were recorded.

3. With the subject standing, an electrocardiograph Z lead was attached to the subject's chest. Specifically, the lead consisted

of an electrode on the left border of the sternum at the fifth interspace, a second placed just to the left of the spinal column at the same level as the first, and a ground electrode placed on the left wrist. A salt-based paste was used to improve the contact of the electrodes with the skin.

4. The subject assumed a supine position on a standard hospital bed with the back of his neck resting on a rolled pillow, thus elevating the chin. Elevating the chin made the detection of the carotid pulse easier and the tracings of the pulse clearer.

5. With the subject in the reclining position a microphone was placed on the chest in a position where it produced the best recording of the second heart sound. Normally this was in the vicinity of the second intercostal space at the left border of the sternum.

6. A child's blood pressure cuff was attached around the lower part of the rib cage or around the abdomen. The cuff bladder was attached to a pressure transducer and was used to record the phases of respiration.

7. A second transducer was positioned near the subject's neck, but resting on the bed. Flexible rubber tubing connected a stethoscope bell to the strain gauge. The left carotid pulse was palpated and the bell placed over the point where the pulse was the greatest. The subject was then asked to hold the bell in place with his right hand for the duration of the test.

8. When all of the appliances were in place, the positions of the markers were adjusted and sensitivities set to produce tracings that would be easy to read. The electrocardiogram was calibrated so that one millivolt equaled a one centimeter deflection. The elapsed time from Step 4 through Step 8 was about ten minutes.

9. A tracing was taken for approximately twenty heart beats.

10. The applicances were removed from the subject and the test was ended.

Measurements

Total Systole (TS): Measured from the beginning of the Q wave (or the R wave if no Q wave was present) of the electrocardiogram to the beginning of the second heart sound of the phonocardiogram (7, 41). The duration of TS was recorded in milliseconds. This measure is shown in Figure 2-1.

Ejection Period (EP): Measured from the foot of the anacrotic limb of the carotid pulse to the dicrotic notch. The duration of EP was recorded in milliseconds (53).

Tension Period (TP): Derived from the formula TS - EP = TP. The so-called "isometric contraction time" of the left ventricle. The duration of TP was recorded in milliseconds. Six determinations of TP were made on each subject at each test, three during inspiration and three during expiration. The beats were measured in a continuous fashion except when a beat was of poor quality or when one set had reached its limit of three while the other had not. The latter was a

common occurrence since expiration was usually the longer of the two respiratory phases.

A brief study of Figure 2-1 will show that a three channel recorder is necessary to measure TP. Coyne (12) used a two channel recorder in his study. He recorded first the electrocardiogram and the phonocardiogram and then the electrocardiogram and the carotid pulse. Since it is well known that the R-R interval changes from beat to beat, and hence TS and EP (53, 54), the validity of this technique cannot be accepted. Also, the constant switching of sensing devices would not allow them to become stable before the measurements were made.

Investigators, like Raab, have measured ten consecutive beats and averaged the results. While this technique is preferable to taking one measure, it does not take into consideration changes that might occur during only one phase of respiration. The changes of TS, EP, and TP during respiration have not been studied. The design of this study permits such an analysis.

Q-Q: The time between the onset of one Q wave and the onset of the next Q wave of the electrocardiogram. The time was recorded in milliseconds. This measure is similar to the R-R method of calculating heart rates, except that different landmarks are used. The Q-Q interval was used because TS included Q in its measurement. The use of Q-Q avoided the overlapping of heart rate and TS measures. Q-Q was measured for each TP measured. The Q-Q values were then converted

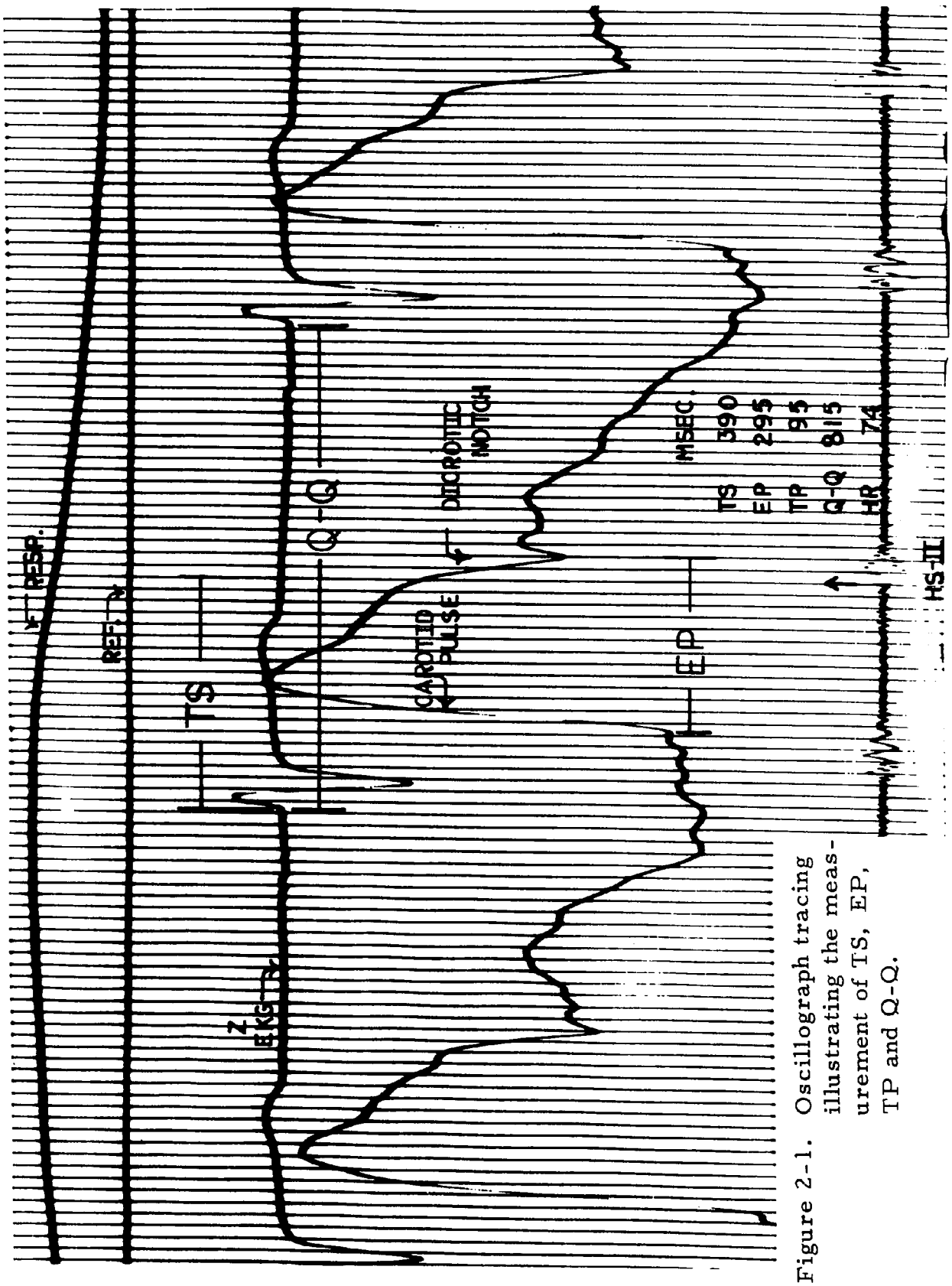


Figure 2-1. Oscillograph tracing illustrating the measurement of TS, EP, TP and Q-Q.

to a beat-to-beat heart rate by using the formula 60,000/Q-Q = heart rate in beats per minute.

Statistical Analysis

Previous studies have reported a negative correlation between heart rate and TP (28, 31). Similarly, Weissler (53, 54) has found a negative correlation between heart rate and EP and heart rate and TS. Since some of the increases in TP reported by Raab and others could be due to bradycardia brought about by physical conditioning, a linear regression analysis was run between heart rate and TS, EP and TP. The combined values for TS, EP, and TP for the four tests were used in calculating the regression coefficient (a). The regression coefficients for these data were:

$a_{TS} = -1.276$

$a_{EP} = -.880$

$a_{TP} = -.388$

$\bar{X}_{HR} = 59.81$

In this group TS decreased 1.276 milliseconds for each beat increase in heart rate. To correct for the linear effects of heart rate, each score was adjusted to a predicted value at the group's mean heart rate. That is, the TS's, EP's and TP's were adjusted to answer the question, "If the subject's heart rate were at the group mean, what would be the values of TS, EP, and TP?" The following formula was used to adjust the raw values:

$$Y' = Y + a(X - \bar{X})$$

where Y' = The adjusted value for TS, EP, or TP.

Y = The observed value for TS, EP, or TP.

a = The regression coefficient.

X = The observed heart rate.

$\overline{X}$ = The mean heart rate.

The heart rate adjusted values (Y''s) were subsequently used in all statistical procedures. The six measures of each variable were averaged with the mean serving as the single observation representing the subject in subsequent statistical analyses. Similarly, for each test, the six measures were divided into those made during inspiration and those made during expiration. There were three measures in each group. The means of these categories were computed and used in the subsequent statistical analyses related to the effects of respiration on the variables under study.

The statistical computations were done by the IBM 7090 computer at the University of Michigan and the IBM 360 computer at Clemson University. The following statistical analyses were carried out.

1. Least-squares analysis of variance of all measures except age for T-1 vs T-2 vs T-3 vs T-4.

2. Intercorrelation coefficients for all variables for T-1, T-2, T-3 and T-4.

In the least-squares analysis of variance procedure, the means are estimated relative to an overall base. That is, the means are

weighted for any disproportionality among the groups. The estimate is unbiased and is responsible for the loss of an additional degree of freedom from the denominator.

CHAPTER III

RESULTS AND DISCUSSION: DIURNAL VARIATION STUDY

Results

Least-squares analysis of variance of fifteen variables did not yield an F value that was significant at the five percent level of significance. Table 3-1 shows the means, standard deviations and F's of these analyses.

Intercorrelation of the fifteen variables and age yielded many significant correlation coefficients. This was to be expected, since many of the variables are closely related. Intercorrelation matrices for these measures will be found in the Appendix, Tables A-1 through A-4.

The correlation coefficients for TS, EP and TP with heart rate decreased after adjusting the values to the mean heart rate. The coefficients were not significant at the .05 level. Age was significantly and positively correlated with heart rate at Test One ($r = .73$), but not at the subsequent tests. Neither raw TP nor TP adjusted for heart rate was significantly correlated with age.

Discussion

The results of the statistical analysis demonstrate that the tension period, as well as total systole and ejection period, does not change significantly throughout the day if the subject has refrained from the use of tobacco and caffeine-containing products. Subjects may be tested at any time of the day, even an hour after eating, without encountering a change in the tension period.

The reduction in the correlation coefficients of TS, EP and TP with heart rate brought about by the adjustment procedure was sufficient to eliminate the effects of heart rate on the tension period. Adjustments for heart rate variations should be made since the heart rate is related to age and physical condition.

The unadjusted tension period and the adjusted tension period were not significantly correlated with age. This is contrary to the findings of other investigators (28, 36).

TABLE 3-1

SUMMARY OF THE MEANS, STANDARD DEVIATIONS AND F'S OF THE SIXTEEN VARIABLES MEASURED IN THE DIURNAL VARIATION GROUP

T-1 vs T-2 vs T-3 vs T-4
N = 9

Variable	Test	Mean	Standard Deviation	Comparisons	F[a]
Age	1-4	27.8	5.5	None	None
Heart Rate (b/min)	1	59	8	1 < 2, 1 < 3	.20
	2	61	10	2 > 3, 2 > 4	
	3	59	6	3 < 4	
	4	60	8	1 < 4	
Raw TS (msec)	1	425	21	1 > 2, 1 > 3	.80
	2	414	23	2 < 3, 2 > 4	
	3	416	11	3 > 4	
	4	413	12	1 > 4	
Raw EP (msec)	1	320	13	1 > 2, 1 > 3	.61
	2	315	15	2 = 3, 2 > 4	
	3	315	9	3 > 4	
	4	312	8	1 > 4	
Raw TP (msec)	1	105	10	1 > 2, 1 > 3	.84
	2	100	11	2 = 3, 2 = 4	
	3	100	7	3 = 4	
	4	100	6	1 > 4	
Adj. TS (msec)	1	423	15	1 > 2, 1 > 3	1.08
	2	416	15	2 > 3, 2 > 4	
	3	415	8	3 > 4	
	4	413	11	1 > 4	
Adj. EP (msec)	1	319	10	1 > 2, 1 > 3	.88
	2	316	10	2 > 3, 2 > 4	
	3	315	6	3 > 4	
	4	313	8	1 > 4	

[a]Least-squares F.

$F_{.95}(3,31) = 2.93$

TABLE 3-1--Continued

Variable	Test	Mean	Standard Deviation	Comparisons	F[a]
Adj. TP (msec)	1	104	8	1 > 2, 1 > 3	.74
	2	100	10	2 = 3, 2 = 4	
	3	100	7	3 = 4	
	4	100	6	1 > 4	
Heart Rate Inspiration (b/min)	1	61	7	1 < 2, 1 > 3	.15
	2	62	11	2 > 3, 2 > 4	
	3	59	5	3 < 4	
	4	60	8	1 > 4	
Adj. TS Inspiration (msec)	1	423	18	1 > 2, 1 > 3	1.13
	2	417	16	2 > 3, 2 > 4	
	3	413	11	3 > 4	
	4	412	11	1 > 4	
Adj. EP Inspiration (msec)	1	318	13	1 > 2, 1 > 3	.64
	2	316	11	2 > 3, 2 > 4	
	3	315	9	3 > 4	
	4	312	8	1 > 4	
Adj. TP Inspiration (msec)	1	105	7	1 > 2, 1 > 3	.87
	2	102	10	2 > 3, 2 > 4	
	3	99	10	3 < 4	
	4	100	7	1 > 4	
Heart Rate Expiration (b/min)	1	57	10	1 < 2, 1 < 3	.34
	2	61	10	2 > 3, 2 > 4	
	3	59	9	3 < 4	
	4	60	8	1 < 4	
Adj. TS Expiration (msec)	1	423	13	1 > 2, 1 > 3	1.04
	2	416	14	2 < 3, 2 > 4	
	3	417	5	3 > 4	
	4	414	12	1 > 4	
Adj. EP Expiration (msec)	1	319	8	1 > 2, 1 > 3	1.14
	2	316	8	2 > 3, 2 > 4	
	3	315	6	3 > 4	
	4	313	8	1 > 4	
Adj. TP Expiration (msec)	1	103	10	1 > 2, 1 > 3	.55
	2	100	9	2 < 3, 2 < 4	
	3	102	6	3 > 4	
	4	101	6	1 > 4	

[a]Least-squares F.

$F_{.95}(3,31) = 2.93$

CHAPTER IV

METHODOLOGY: PHYSICAL TRAINING STUDY

Subjects

This portion of the study was designed to determine the effects of a strenuous physical conditioning program on the duration of the tension period. Comparisons were made between a group of athletes and non-athletes, and between two groups of non-athletes. One of the non-athlete groups participated in a physical conditioning program while the control group did not.

Athlete Group (Group S): Fifteen freshmen and varsity swimmers from the University of Michigan swimming team participated in this group. Participation in the study was on a voluntary basis. Each subject was asked to participate in the study immediately after he had finished his competitive season. All subjects in this group were tested within ten days of their last competition. Because of the multitude of "championship" meets, the testing of these subjects was staggered with the better swimmers being tested later in the school year.

Non-Athlete Groups: The subjects in these groups were all undergraduate students at the University of Michigan. While there were several upperclassmen, the majority of these subjects was freshmen. Each subject had at least one semester of a physical education

requirement to fulfill. The subjects elected to take a special fitness course which would meet one hour a day, five days a week for five weeks. All subjects were informed of the following factors before making their final decision to elect the course.

1. The course would be more strenuous than the general courses offered in the Service Program.

2. Running would comprise a major portion of the physical activity.

3. Laboratory tests would be made that would require extra time. The nature of these tests was explained.

4. The students would be randomly assigned to either an experimental or control group.

5. Five members of each group would be randomly selected to take additional tests.

No attempt was made to discourage an interested student from selecting this course unless he had some physical handicap that would severely limit his ability to participate in the activities.

Fifty students were enrolled in the course. At the time of enrollment they were given directions for finding the laboratory and were scheduled for the first round of tests. Each subject was given a slip of paper with the time and place of the test along with two statements asking that products containing caffeine, nicotine or any other stimulant not be used for three hours prior to the test. Furthermore, the subjects were asked to refrain from moderate or vigorous physical

activity for three hours prior to the test. In particular, they were advised to be late rather than hurry to the test center should time slip by them.

After the fifty subjects had been enrolled, each was assigned to one of two groups by drawing names from a hat. Within each group, the subjects were arranged in alphabetical order. Using a randomly selected number between one and twenty five as a starting point, every fifth subject was selected to take the additional tests. Different starting points were randomly selected for Group A and Group B.

Design

The two groups of subjects completed Test One (T-1) together. At T-1 each subject was informed of his group membership. Group A was the experimental group, while the subjects in Group B served as controls. The members of Group B were asked to refrain from any increases in their normal daily physical activity for the subsequent five weeks. They were further informed that they would be contacted for their second test (T-2) some four weeks hence. Group A reported for the first class of the five-week conditioning period on the Monday following the tests.

Group B completed T-2 while Group A was in its fifth week of training. Group A was tested within five days after the completion of the training period. At this point the roles were switched. Group B participated in essentially the same five-week conditioning program while Group A entered a detraining period. While Group B was in its

fifth week of the conditioning program, Group A completed T-3. Group B completed its third test within five days of the last day of class.

The test arrangement permitted the investigator to look at the effects of training on the variables using both the Experimental subjects and the Control subjects as control. Changes in Group A due to conditioning may be distinguished from changes in the general population over the same period of time by comparing Group A with Group B at T-1 and T-2. The significance of any changes occurring in Group A at T-2 may be determined through comparisons with T-1 scores. That Group B represents a sample of the same population from which Group A was drawn may be demonstrated by comparisons of the two groups before conditioning and, secondly, by demonstrating that the conditioning program had the same effects on Group B as it did on Group A. The detraining of Group A should show a reversal of any nonpermanent changes brought about by the conditioning program, thus proving the relationship between physical conditioning and these changes (34).

Finally, the comparison of the Athlete Group with Groups A and B offers an opportunity to study the extreme effects of training on the variables under observation.

Using subjects of the same age and occupational group minimizes the effects of age and occupation on the variables. While this limits the applicability of the results of the study, it increases the

precision by limiting the effects of unknown and/or unmeasured factors on the variables being studied.

Limitations: The obvious limitations of this study are of restrictions placed on it by the selection of the sample. Since the subjects are students at the University of Michigan, the results may only be representative of these students and swimmers (athletes). Furthermore, since the students selected a rigorous activity program the Experimental-Control sample is only representative of those persons who wished to elect "Fitness" as their physical education course. However, it seems reasonable that the results of this study should be indicative of the results to be expected in similar studies conducted under similar conditions at other colleges and universities.

Due to the relatively small samples, the limitations of sample size must play a role in the determination of significant differences among the variables under the various conditions.

Variables Studied

All the variables included in the Diurnal Variation Study were included in the physical conditioning study. The following variables were also included.

Anthropometric Data: Measure of height, weight and age were taken on all subjects.

Harvard Step Test Score (HST): The Harvard Step Test Score (38, p. 316) was used as the indicator of the level of physical condition achieved by each subject.

Maximum Oxygen Uptake ($\dot{V}O_2$): This measure was recorded on the sub-sample of five subjects each from Groups A, B and S.

Ventilation ($\dot{V}_E$): The minute volume of air moved at the level of work at which maximum oxygen intake was recorded.

Instrumentation

Instrumentation used in addition to that described in Chapter II included:

Rule: A six-foot six-inch ruler was used to measure height. Each subject was measured without shoes.

Scales: At the electrocardiographic tests weight was measured on a Borg home scale. Weight at the oxygen uptake tests was measured on a balance beam scale. The scales gave readings within one pound of each other when several individuals were tested on one and then the other at the same time. The subjects were weighed without shoes.

Stop Watch and Stethoscope: These instruments were used to measure the recovery heart rates used in determining the Harvard Step Test Scores.

Neoprene Bags: All gas collections were made in these bags. Each bag was evacuated before being used to collect a gas sample.

Fisher-Hamilton Gas Partitioner: Samples of expired air were analyzed with the Gas Partitioner. The output of the Partitioner was recorded on a Bristol recorder.

Gasometer: A Collins six hundred liter Gasometer was used to measure expired gas volumes. After the sample had been taken for

analysis the neoprene bag was emptied into the Gasometer with the aid of a vacuum pump.

Test Procedure

The subjects in Groups A, B, and S followed the same electrocardiographic test procedure as the Diurnal Variation subjects, but with the following additions:

1. Immediately before the subject was prepared for the electrocardiographic test his height and weight were measured.

2. After the twenty second tracing was made on the oscillograph, the subject was asked to sit up. All appliances except the electrocardiograph leads were then removed.

3. The subject walked, holding the electrocardiograph lead cable, to an adjoining room where the procedures of the Harvard Step Test were explained. The subject then took the test.

4. For the last fifteen seconds of the test, the electrocardiogram was taken. However, due to muscle potential interference these tracings were of too poor quality to analyze.

5. At the end of exercise the subject walked back to the original test room a distance of five feet, and sat down. A thirty-second recovery pulse count was taken by auscultation, but was also recorded on the electrocardiograph.

6. The electrocardiograph leads were then removed. The entire test terminated at this point.

The subjects selected to take the oxygen uptake test were scheduled at the time of the electrocardiographic test. The oxygen uptake test proceeded as follows:

1. The subject entered the laboratory and changed into any uniform that he had with him.

2. The subject was weighed without shoes.

3. The subject was escorted into the exercise room and mounted the treadmill. Before the exercise started he was informed of the test procedure and was allowed time to get accustomed to the mouthpiece, nose clip and valve system used in gas collection. These were then removed until the final two minutes of exercise.

4. The subject executed the test which required him to walk on the treadmill at a grade increasing with time, until he was exhausted. Samples of expired air were collected during the last two minutes of exercise. If at T-2 the subject continued on the treadmill for a longer period of time than he had at T-1, gas samples were taken at the time when he had reached exhaustion at T-1, as well as when he reached exhaustion at T-2. The same procedure was used at T-3. However, samples were not taken at a time corresponding to T-2 exhaustion during T-3. Heart rates were taken by palpation of the carotid artery at the various levels of work to aid the observers in determining the effects of each level on the subject.

5. After the test the subject was allowed to recover, shower and leave.

Fitness Tests

The Harvard Step Test: This test required the subject to step up and down on a twenty-inch bench at the rate of thirty ascents and descents per minute for five minutes. At the end of the test the subject was seated. A thirty second pulse rate was taken from sixty to ninety seconds after exercise (8). The Physical Efficiency Index may be calculated with the formula

$$PEI = \frac{\text{Duration of Exercise in Seconds} \times 100}{5.5 \times \text{Pulse County 60-90 Seconds After Exercise}}$$

However, tabled values exist for this formula and were used in this study (38).

The Harvard test was selected for several reasons. It was originally designed for the population age group of this study. Several studies have shown that the PEI changes with the level of physical condition of the subjects and is particularly sensitive to training (9, 10, 30, 33). Finally, the test was chosen because it required a maximum of ten minutes to administer. This made it possible to give the test in conjunction with the electrocardiographic tests and to complete both tests within a week of the termination of training. It was necessary to test the subjects as soon as possible after the end of the conditioning program so that the test would be indicative of the subject at his peak fitness level under the training program.

The Oxygen Uptake: The Oxygen Uptake test was a modification of the Balke Treadmill Test (4). The subject walked on a motor driven treadmill at four and two-tenths miles per hour. Every two minutes

the grade was increased five percent. Heart rates were taken after the subject had been at each level for one minute. If the subject showed signs of exhaustion and had a heart rate of approximately one hundred and seventy beats per minute, the grade was increased only two and one-half percent for the last two minutes of exercise. Since the maximum elevation of the treadmill was twenty percent, the speed of the belt was increased to four and six-tenths miles per hour for any of the subjects who were not exhausted at the slower speed. Treadmill speeds were calibrated for each subject and each speed level with a stop watch.

When the subject felt that he could continue for only two more minutes, he inserted the mouthpiece of the one-way valve apparatus into his mouth. Successive thirty second expired gas samples were taken until the subject was exhausted. By means of a three-way valve, the samples were continuously collected in neoprene bags. The bags were sealed with a stopper and set aside for analysis.

Before each test the Fisher-Hamilton Gas Partitioner was calibrated with a reference gas. A small sample of expired gas was fed into the machine at a constant flow rate. The results of the analysis were recorded on a Bristol recorder and on a data sheet. All of the gas analyses were done by the same trained technician. The neoprene bags were then evacuated into a Tissot gasometer (Collins) and the volumes recorded.

Measurements

The measurements of total systole, ejection period, tension period and heart rate were described in Chapter II. These measurements were taken in the same manner on Groups A, B and S. However, instead of making six measurements of each variable, ten measurements were taken, five during inspiration and five during expiration. Other measures taken were:

Height: Recorded in inches.

Weight: Recorded in pounds, except for the oxygen uptake sample in which kilograms were used.

Maximum Oxygen Uptake: This value was calculated from the readings of the Fisher-Hamilton Gas Partitioner. The percentages of oxygen and carbon dioxide were calculated. The sum of the oxygen and carbon dioxide percentages was subtracted from one hundred to get the percentage of nitrogen. Oxygen uptake was determined by substituting in the formula $\dot{V}_{O_2} = \dot{V}_E(.2648\ F_{EN_2} - F_{EO_2})$

where $\dot{V}_{O_2}$ = Maximum oxygen uptake in liters per minute.

$\dot{V}_E$ = Minute ventilation in liters, corrected to standard temperature and pressure dry (STPD), at the time the gas sample was taken.

F_{EN_2} = The percentage of expired nitrogen in the sample.

F_{EO_2} = The percentage of expired oxygen in the sample.

.2648 = A constant correction factor for the inspired gas volume. It is derived from the ratio 20.93/79.04 (11).

Maximum Oxygen Uptake per Kilogram of Body Weight per Minute: The maximum oxygen uptake as determined above divided by the subject's weight in kilograms. Expressed in milliliters of oxygen per kilogram of body weight per minute (ml/kg/min).

Ventilation: Ventilation ($\dot{V}_E$) volumes were measured in a Tissot gasometer. They were corrected to STPD and were recorded in liters.

Conditioning Program

The conditioning program consisted of approximately forty-five minutes of vigorous calisthenics, running and games. The program was varied from day to day with some days being more strenuous than others. The normal level of energy expenditure for a class period was estimated as being equivalent to twelve times the basal metabolic rate (44).

For the average subject five feet eleven inches, one hundred and fifty-six pounds and eighteen and one-half years old, the energy expenditure as calculated from the Mayo Foundation Normal Standards charts (from W. E. Collins, Inc.) was equal to approximately nine hundred and seventy-five kilocalories per hour, or seven hundred and thirty kilocalories per forty-five minute class. The intensity of the exercises was rated at twelve times the basal metabolic rate on the average (44). This energy expenditure was probably equal to about one-fourth of the student's daily preconditioning energy expenditure based on a total daily energy expenditure of 2800-3000 kilocalories (19, 51). Previous studies indicate that ". . . an energy expenditure

greater than seven hundred Calories per hour cannot be continued for much longer than one hour by the average man" (38). While the energy expenditure in class was considerably higher than seven hundred kilocalories per hour, the subjects were judged to be in better than average physical condition at Test One. It was believed that an energy expenditure of this magnitude would be sufficient to produce a "training effect" on the Harvard Step Test scores and Maximum Oxygen Uptake.

Statistical Analysis

Of the fifty subjects that entered the study, only thirty-six completed the entire testing program. The final count had twenty subjects in Group A and sixteen in Group B. Likewise, only four of the five subjects selected from Group A and four of five from Group B completed all of the oxygen uptake tests. There seemed to be no one reason for the loss of the subjects. Several suffered injuries in activities outside of the exercise period which limited their ability to participate in any form of vigorous activities. Other students had schedule changes that made it impossible to attend class. Illnesses such as infectious mononucleosis forced at least two withdrawals. A few subjects dropped from sight without giving an explanation. It is possible that these dropped the study because the exercise was too vigorous, but there are also many other possible reasons. The apparent lack of any consistent reason for dropping out of the study suggests that the subjects who dropped did not constitute a homogeneous subgroup whose absence would bias the results of the study.

The various statistical procedures were run on only the results from subjects who had completed all of the required tests. The least-squares analysis of variance technique was used whenever two or more means were compared. When an analysis of variance yielded a significant F, the Newman-Kuels procedure (57, p. 80) was used to determine the location of the significant difference. A .05 level of significance was set for each test.

The following statistical analyses were carried out:

1. Analysis of variance on the Group A data T-1 vs T-2 vs T-3 on seventeen variables (Table 5-2).

2. Analysis of variance on the Group B data T-1 vs T-2 vs T-3 on seventeen variables (Table 5-3).

3. Analysis of variance on the differences between Groups A and B at T-1 (Table 5-4), T-2 (Table 5-5), and T-3 (Table 5-6) on nineteen variables.

4. Analysis of variance on the changes in the Group A subgroup between T-1, T-2 and T-3 oxygen uptake variables (Table 5-7).

5. Analysis of variance on the changes in the Group B subgroup between T-1, T-2 and T-3 oxygen uptake variables (Table 5-8).

6. Analysis of variance on the differences between Group A and B oxygen uptake subgroups at T-1 (Table 5-9), T-2 (Table 5-10), and T-3 (Table 5-11).

7. Correlated "t" test on variables TS, EP, TP and heart rate measured during inspiration and expiration (Table 5-1).

8. Linear intercorrelation of nineteen variables for Group A (Tables A-5, A-6, A-7) and Group B (Tables A-8, A-9, A-10) for Tests 1, 2 and 3 respectively.

9. Linear intercorrelation of the oxygen uptake variables for the Group A subgroup (Tables A-12, A-13, A-14) and the Group B subgroup (Tables A-15, A-16, A-17) for Tests 1, 2 and 3 respectively.

10. Analysis of variance on the differences between Group A and B combined and Group S at T-1 for nineteen variables (Table 5-12).

11. Analysis of variance on the differences between the oxygen uptake subgroups of A and B combined and the oxygen uptake subgroup of Group S (Table 5-13).

The variables TS, EP and TP were adjusted for heart rate using the following regression coefficients:

$a_{TS} = -1.157$ $\qquad$ $\bar{X}_{HR} = 66.34$

$a_{EP} = -1.144$

$a_{TP} = -.025$

CHAPTER V

RESULTS: PHYSICAL TRAINING STUDY

There were no significant differences between adjusted TS, EP, TP and heart rate when measurements made during inspiration and expiration were compared (Table 5-1). The sinus arrhythmia phenomenon that decreases the heart rate during expiration was not pronounced enough to cause a significant change in heart rate (19, p. 431).

The physical condition of Group A improved significantly between T-1 and T-2, as shown by the significant difference in the Step Test scores (Table 5-2). The detraining period also produced a significant retrogression that supports the contention that the change in Step Test scores was due to the physical conditioning program (Figure 5-1). Group B did not change significantly between either T-1 and T-2 or T-2 and T-3.

Total systole and ejection period in Group A changed significantly between T-1 and T-2, and between T-2 and T-3. Heart rate also changed significantly. When TS and EP were adjusted for heart rate the changes between tests were not significant. Heart rate, TS and EP did not change significantly in Group B.

Intergroup comparisons showed that there were no significant differences between Group A's and Group B's physical condition at the beginning of the study. However, at T-2 Group A was in significantly better physical condition than the control group (Tables 5-4, 5-5, 5-6). Resting heart rate was significantly lower in Group A at T-2. There were no other significant between-test differences of the remaining variables. In particular, TP proved to be one of the most stable of the measurements. In Group A where physical condition improved significantly TP correlated between -.09 and .00 with the Step Test. When TP was correlated with the oxygen uptake measures, the coefficients varied widely from test to test. This wide variation was probably an artifact introduced by the small sample.

In the oxygen uptake subgroup, Group A experienced no significant changes between tests. Group B improved significantly in maximum oxygen uptake (ml/kg/min) between each of the tests. When oxygen uptake at a constant work level (CWL) both for $\dot{V}O_2$ (ml/kg/min) and for $\dot{V}O_2$ (L/min) was compared, it was significantly improved between T-1 and T-3 and between T-2 and T-3. Ventilation at CWL oxygen uptake also increased significantly in Group B between T-1 and T-3 and between T-2 and T-3. When Group A was compared with Group B at each test only the Step Test scores at T-2 were significantly different.

Figures 5-1 and 5-2 clearly show the course of physical conditioning in the subjects in Group A and Group B. While not all

of the changes were significant the heart rate and Step Test score patterns are typical of persons undertaking a training program. Note that three of the four variables in oxygen uptake Group A continued to improve after five weeks of detraining, this in spite of a significant decrease in the Step Test scores. With the exception of ventilation, oxygen uptake and Step Test scores improved in Group B with each test.

Comparisons between the athletes and Group A and B showed that the athletes were significantly taller, heavier, and in better physical condition than the non-athletes. Furthermore, the athletes had higher maximum oxygen uptakes, both in liters per minute and in milliliters per kilogram of body weight per minute (Tables 5-12, 5-13). There were no significant differences between groups for the variables of adjusted TS, EP and TP.

TABLE 5-1

SUMMARY OF THE DIFFERENCES IN TS, EP, TP AND HEART RATE DURING INSPIRATION AND EXPIRATION[a]

N = 36

Variable	Inspiration Mean	Expiration Mean	r	t
Adj. TS (msec)	386	385	.83	.40
Adj. EP (msec)	296	293	.86	1.11
Adj. TP (msec)	90	92	.93	-.92
Heart Rate (b/min)	68	65	.93	1.39

$t_{.975} = 2.03$

[a]These data are from the combined Group A and B at T-1.

TABLE 5-2

SUMMARY OF THE MEANS, STANDARD DEVIATIONS AND F'S OF THE NINETEEN VARIABLES MEASURED IN GROUP A

T-1 vs T-2 vs T-3
N = 20

Variable	Test	Mean	Standard Deviation	Comparisons	F[a]
Age (yr)	1	18.4	0.9	None	
Height (in.)	1	71.1	2.8	None	
Weight (lb.)	1	158	18	1 < 2	.08
	2	160	19	2 = 3	
	3	160	18	1 < 3	
Heart Rate (b/min)	1	68	9	1 > 2*	4.03*
	2	62	10	2 < 3*	
	3	70	10	1 < 3	
Raw TS (msec)	1	382	18	1 < 2*	3.32*
	2	396	20	2 > 3*	
	3	382	21	1 = 3	
Raw EP (msec)	1	292	17	1 < 2*	4.59*
	2	305	15	2 > 3*	
	3	290	17	1 > 3	
Raw TP (msec)	1	90	10	1 < 2	.22
	2	92	10	2 = 3	
	3	92	7	1 < 3	
Adj. TS (msec)	1	384	12	1 < 2	1.42
	2	391	14	2 > 3	
	3	387	14	1 < 3	
Adj. EP (msec)	1	293	12	1 < 2	1.81
	2	299	11	2 > 3	
	3	294	9	1 = 3	

*$p \leq .05$

$F_{.95}(2, 57) = 3.17$

[a]Least-squares F.

TABLE 5-2--Continued

Variable	Test	Mean	Standard Deviation	Comparisons	F[a]
Adj. TP (msec)	1	90	10	1 < 2	.23
	2	92	10	2 = 3	
	3	92	7	1 < 3	
Heart Rate Inspiration (b/min)	1	69	9	1 > 2*	4.60*
	2	63	10	2 < 3*	
	3	72	10	1 < 3	
TS Inspiration (msec)	1	384	13	1 < 2	1.61
	2	392	14	2 > 3	
	3	387	15	1 < 3	
EP Inspiration (msec)	1	295	12	1 < 2	1.23
	2	300	11	2 > 3	
	3	296	10	1 < 3	
TP Inspiration (msec)	1	89	10	1 < 2	.61
	2	92	10	2 > 3	
	3	91	8	1 < 3	
Heart Rate Expiration (b/min)	1	67	9	1 > 2*	3.51*
	2	60	10	2 < 3*	
	3	68	11	1 < 3	
TS Expiration (msec)	1	383	11	1 < 2	1.39
	2	390	14	2 > 3	
	3	386	15	1 < 3	
EP Expiration (msec)	1	291	13	1 < 2	2.18
	2	299	11	2 > 3	
	3	293	10	1 < 3	
TP Expiration (msec)	1	92	10	1 > 2	.27
	2	91	11	2 < 3	
	3	93	8	1 < 3	
Step Test Score	1	76	10	1 < 2*	5.97*
	2	86	8	2 > 3*	
	3	79	10	1 < 3	

*$p \leq .05$ $F_{.95}(2, 57) = 3.17$

[a]Least-squares F.

TABLE 5-3

SUMMARY OF THE MEANS, STANDARD DEVIATIONS AND F'S OF THE NINETEEN VARIABLES MEASURED IN GROUP B

T-1 vs T-2 vs T-3
N = 16

Variable	Test	Mean	Standard Deviation	Comparisons	F[a]
Age (yr)	1	18.5	1.3	None	
Height (in.)	1	70.5	2.7	None	
Weight (lb.)	1	157	19	1 < 2	.04
	2	158	19	2 < 3	
	3	159	19	1 < 3	
Heart Rate (b/min)	1	64	9	1 < 2	1.88
	2	70	10	2 > 3	
	3	65	8	1 = 3	
Raw TS (msec)	1	390	15	1 > 2	.35
	2	388	15	2 < 3	
	3	392	16	1 < 3	
Raw EP (msec)	1	299	18	1 > 2	.15
	2	298	14	2 < 3	
	3	301	17	1 < 3	
Raw TP (msec)	1	91	9	1 = 2	.09
	2	91	9	2 < 3	
	3	92	8	1 < 3	
Adj. TS (msec)	1	388	9	1 < 2	.81
	2	392	12	2 > 3	
	3	391	12	1 < 3	
Adj. EP (msec)	1	296	11	1 < 2	.87
	2	302	10	2 > 3	
	3	298	12	1 < 3	

[a]Least-squares F.

$F_{.95}(2, 45) = 3.22$

TABLE 5-3--Continued

Variable	Test	Mean	Standard Deviation	Comparisons	F[a]
Adj. TP (msec)	1	91	9	1 = 2	.22
	2	91	9	2 < 3	
	3	93	8	1 < 3	
Heart Rate Inspiration (b/min)	1	65	9	1 < 2	1.54
	2	70	9	2 > 3	
	3	66	8	1 < 3	
Adj. TS Inspiration (msec)	1	388	11	1 < 2	.59
	2	392	12	2 = 3	
	3	392	12	1 < 3	
Adj. EP Inspiration (msec)	1	298	13	1 < 2	.32
	2	301	10	2 > 3	
	3	300	12	1 < 3	
Adj. TP Inspiration (msec)	1	90	8	1 < 2	.36
	2	91	9	2 < 3	
	3	93	7	1 < 3	
Heart Rate Expiration (b/min)	1	61	10	1 < 2	2.07
	2	69	10	2 > 3	
	3	63	8	1 < 3	
Adj. TS Expiration (msec)	1	386	8	1 < 2	1.03
	2	392	12	2 > 3	
	3	390	13	1 < 3	
Adj. EP Expiration (msec)	1	294	10	1 < 2	1.57
	2	301	11	2 > 3	
	3	297	13	1 < 3	
Adj. TP Expiration (msec)	1	92	9	1 > 2	.17
	2	91	9	2 < 3	
	3	92	8	1 = 3	
Step Test Score	1	79	10	1 < 2	2.31
	2	81	6	2 < 3	
	3	85	6	1 < 3	

[a]Least-squares F.

$F_{.95}(2,45) = 3.22$

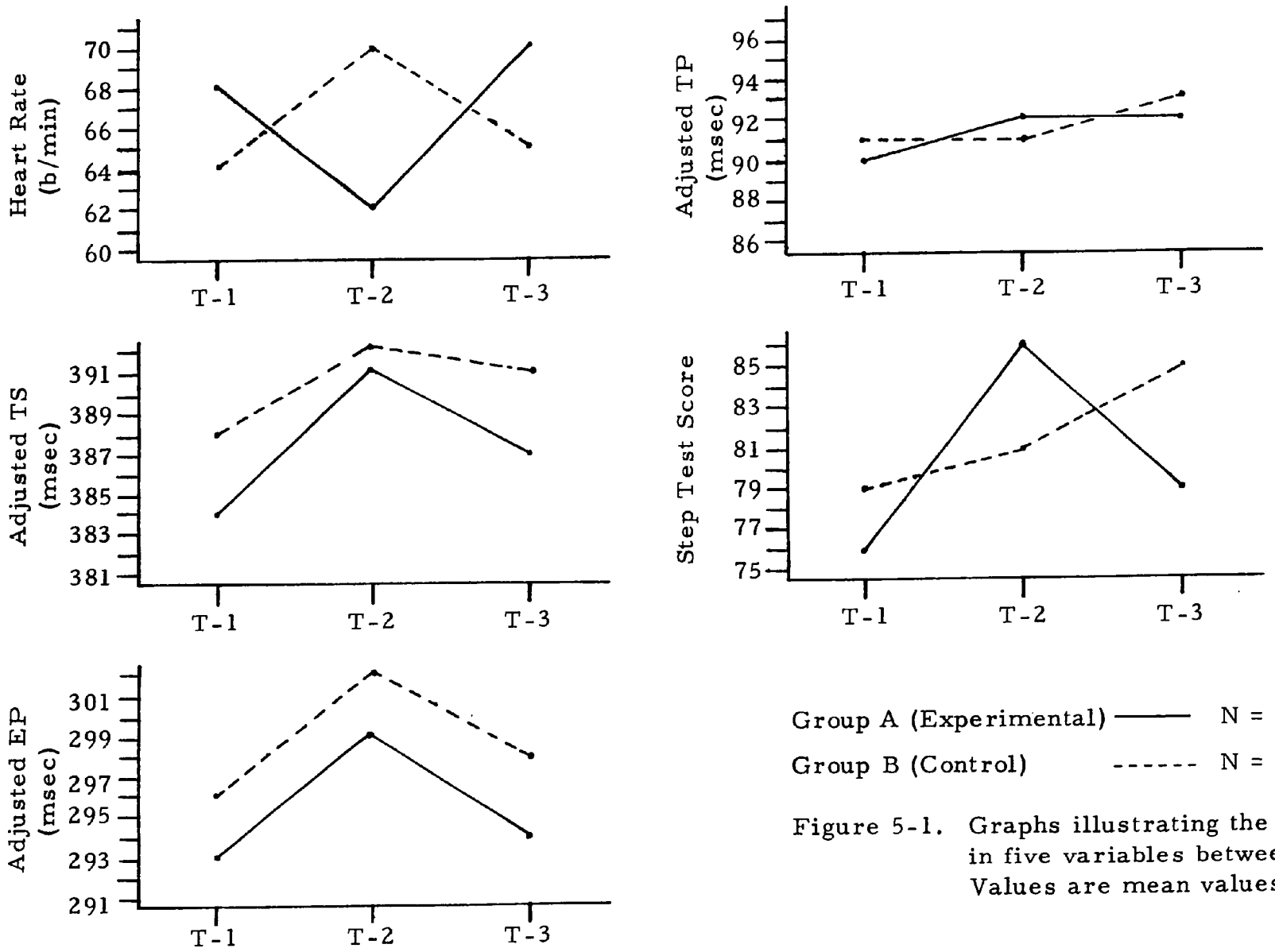


Figure 5-1. Graphs illustrating the changes in five variables between tests. Values are mean values.

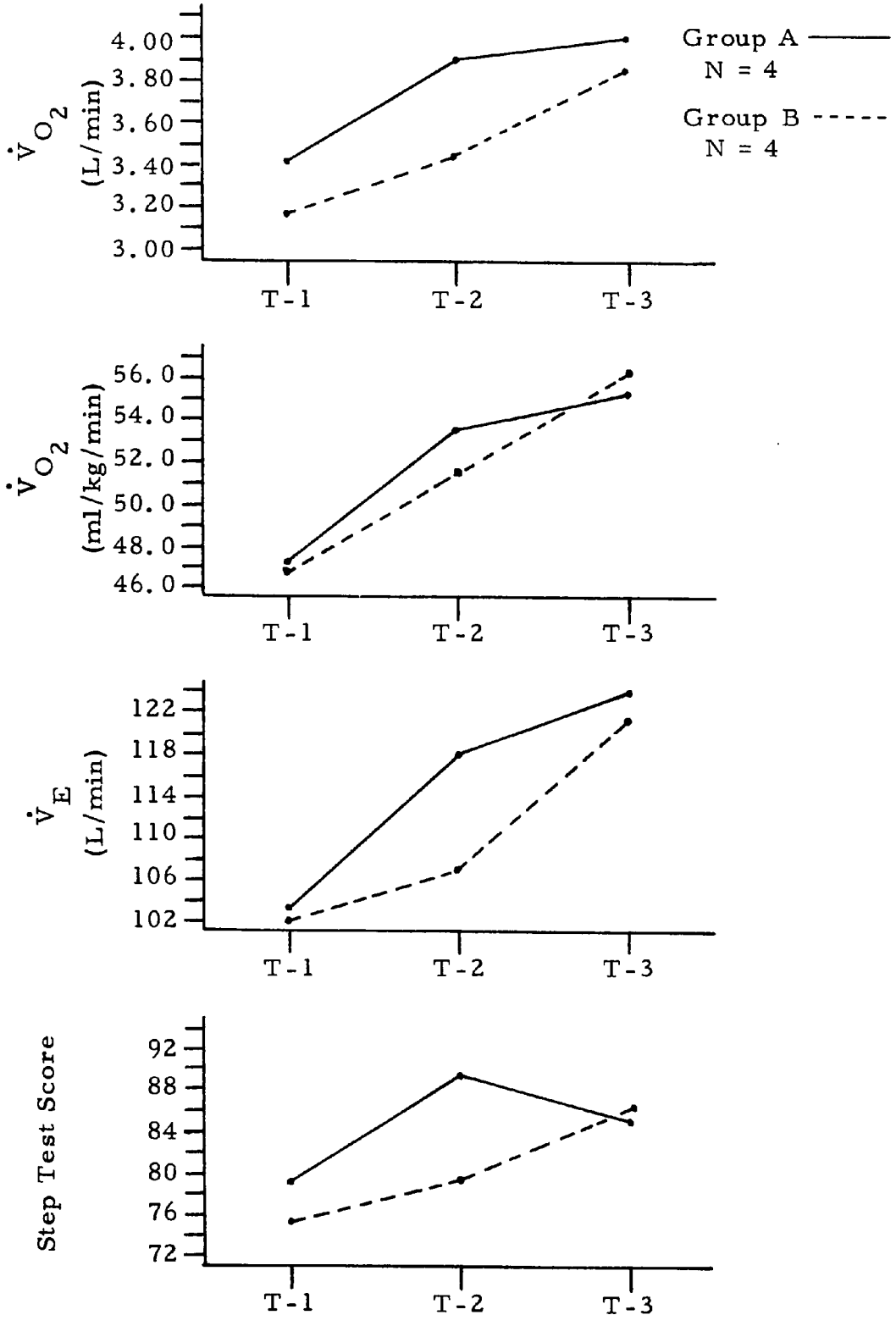


Figure 5-2. Graphs illustrating the changes in four variables between tests. Values are mean values.

TABLE 5-4

SUMMARY OF THE MEANS, STANDARD DEVIATIONS AND F'S FOR THE COMPARISONS BETWEEN GROUP A AND GROUP B[a]

T-1

Variable	Group	Mean	Standard Deviation	Comparisons	F[b]
Age (yr)	A	18.4	0	A < B	.07
	B	18.5	1.3		
Height (in.)	A	71.1	2.8	A > B	.49
	B	70.5	2.7		
Weight (lb.)	A	158	18	A > B	.01
	B	157	19		
Heart Rate (b/min)	A	68	9	A > B	2.07
	B	64	9		
Raw TS (msec)	A	382	18	A < B	2.31
	B	390	15		
Raw EP (msec)	A	292	17	A < B	1.60
	B	299	18		
Raw TP (msec)	A	90	10	A < B	.11
	B	91	9		
Adj. TS (msec)	A	384	12	A < B	1.21
	B	388	9		
Adj. EP (msec)	A	293	12	A < B	.53
	B	296	11		
Adj. TP (msec)	A	90	10	A < B	.08
	B	91	9		
Step Test Score	A	76	10	A < B	1.16
	B	79	10		

[a]Group A, N = 20; Group B, N = 16.

[b]Least-squares F. $F_{.95}(1, 34) = 4.13$

TABLE 5-5

SUMMARY OF THE MEANS, STANDARD DEVIATIONS AND F'S FOR THE COMPARISONS BETWEEN GROUP A AND GROUP B[a]

T-2

Variable	Group	Mean	Standard Deviation	Comparison	F[b]
Weight (lb.)	A	160	19	A > B	.13
	B	158	19		
Heart Rate (b/min)	A	62	10	A < B	5.59*
	B	70	10		
Raw TS (msec)	A	396	20	A > B	1.73
	B	388	15		
Raw EP (msec)	A	305	15	A > B	2.07
	B	298	14		
Raw TP (msec)	A	92	10	A > B	.08
	B	91	9		
Adj. TS (msec)	A	391	14	A < B	.12
	B	392	12		
Adj. EP (msec)	A	299	10	A < B	.35
	B	302	10		
Adj. TP (msec)	A	92	10	A > B	.05
	B	91	9		
Step Test Score	A	86	8	A > B	4.13*
	B	81	6		

*$p \leq .05$ $F_{.95}(1, 34) = 4.13$

[a]Group A, N = 20; Group B, N = 16.

[b]Least-squares F.

TABLE 5-6

SUMMARY OF THE MEANS, STANDARD DEVIATIONS AND F'S FOR THE COMPARISONS BETWEEN GROUP A AND GROUP B[a]

T-3

Variable	Group	Mean	Standard Deviation	Comparison	F[b]
Weight (lb.)	A	160	18	A > B	.01
	B	159	19		
Heart Rate (b/min)	A	70	10	A > B	2.69
	B	65	8		
Raw TS (msec)	A	382	22	A < B	2.59
	B	392	16		
Raw EP (msec)	A	290	17	A < B	3.47
	B	301	17		
Raw TP (msec)	A	92	7	A = B	.01
	B	92	8		
Adj. TS (msec)	A	387	14	A < B	.88
	B	391	12		
Adj. EP (msec)	A	294	9	A < B	1.19
	B	298	12		
Adj. TP (msec)	A	92	7	A < B	.02
	B	93	8		
Step Test Score	A	79	10	A < B	3.91
	B	85	6		

[a]Group A, N = 20; Group B, N = 16.

[b]Least-squares F. $F_{.95}(1, 34) = 4.13$

TABLE 5-7

SUMMARY OF THE MEANS, STANDARD DEVIATIONS AND F'S FOR THE OXYGEN UPTAKE VARIABLES MEASURED ON THE GROUP A SUBSAMPLE

N = 4

Variable	Test	Mean	Standard Deviation	Comparisons	F[a]
Weight (kg)	1	72.5	12	1 < 2	.02
	2	73.7	12	2 > 3	
	3	72.0	14	1 > 3	
$\dot{V}O_2$ (L/min)	1	3.41	0.56	1 < 2	.79
	2	3.91	0.49	2 < 3	
	3	3.98	0.96	1 < 3	
$\dot{V}O_2$ (ml/kg/min)	1	47.2	5	1 < 2	3.26
	2	53.4	4	2 < 3	
	3	55.2	5	1 < 3	
$\dot{V}_E$ (L/min)	1	103	22	1 < 2	.56
	2	118	23	2 < 3	
	3	124	37	1 < 3	
$\dot{V}O_2$ (L/min) Constant Work Level	1	3.32	0.63	1 < 2	.07
	2	3.40	0.47	2 > 3	
	3	3.28	0.35	1 > 3	
$\dot{V}O_2$ (ml/kg/min) Constant Work Level	1	45.8	4	1 < 2	.02
	2	46.6	5	2 = 3	
	3	46.6	10	1 < 3	
$\dot{V}_E$ (L/min) Constant Work Level	1	97	22	1 > 2	.07
	2	92	16	2 < 3	
	3	95	17	1 > 3	

[a]Least-squares F.

$F_{.95}(2, 9) = 4.26$

TABLE 5-7--Continued

Variable	Test	Mean	Standard Deviation	Comparisons	F[a]
Adj. TS (msec)	1	392	17	1 > 2	.49
	2	380	17	2 < 3	
	3	383	18	1 > 3	
Adj. EP (msec)	1	303	15	1 > 2	.55
	2	294	16	2 = 3	
	3	294	11	1 > 3	
Adj. TP (msec)	1	89	5	1 > 2	.10
	2	87	8	2 < 3	
	3	88	7	1 > 3	
Step Test Score	1	79	11	1 < 2	.89
	2	89	6	2 > 3	
	3	85	14	1 < 3	

[a]Least-squares F.

$F_{.95}(2, 9) = 4.26$

TABLE 5-8

SUMMARY OF THE MEANS, STANDARD DEVIATIONS AND F'S FOR THE OXYGEN UPTAKE VARIABLES MEASURED ON THE GROUP B SUBSAMPLE

N = 4

Variable	Test	Mean	Standard Deviation	Comparisons	F[a]
Weight (kg)	1	67.4	6	1 > 2	.07
	2	66.7	5	2 < 3	
	3	68.3	6	1 < 3	
$\dot{V}O_2$ (L/min)	1	3.15	0.40	1 < 2	3.12
	2	3.43	0.34	2 < 3	
	3	3.84	0.44	1 < 3	
$\dot{V}O_2$ (ml/kg/min)	1	46.7	4	1 < 2*	10.87*
	2	51.4	3	2 < 3*	
	3	56.2	2	1 < 3*	
$\dot{V}_E$ (L/min)	1	102	7	1 < 2	3.90
	2	106	6	2 < 3	
	3	121	15	1 < 3	
$\dot{V}O_2$ (L/min) Constant Work Level	1	3.05	0.29	1 > 2*	6.43*
	2	2.78	0.25	2 < 3*	
	3	3.43	0.24	1 < 3*	
$\dot{V}O_2$ (ml/kg/min) Constant Work Level	1	45.3	3	1 > 2*	10.10*
	2	41.6	2	2 < 3*	
	3	50.4	4	1 < 3*	
$\dot{V}_E$ (L/min) Constant Work Level	1	99	5	1 > 2*	5.73*
	2	90	4	2 < 3*	
	3	110	12	1 < 3*	

*$p \leq .05$ [a]Least-squares F. $F_{.95}(2, 9) = 4.26$

TABLE 5-8--Continued

Variable	Test	Mean	Standard Deviation	Comparisons	F[a]
Adj. TS (msec)	1	388	4	1 < 2	.12
	2	392	5	2 > 3	
	3	390	19	1 < 3	
Adj. EP (msec)	1	295	10	1 < 2	.49
	2	304	9	2 > 3	
	3	299	18	1 < 3	
Adj. TP (msec)	1	93	5	1 > 2	.70
	2	88	6	2 < 3	
	3	91	6	1 > 3	
Step Test Score	1	75	15	1 < 2	1.41
	2	79	3	2 < 3	
	3	86	8	1 < 3	

[a]Least-squares F.

$F_{.95}(2, 9) = 4.25$

TABLE 5-9

SUMMARY OF THE MEANS, STANDARD DEVIATIONS AND F'S FOR THE COMPARISONS BETWEEN GROUP A AND GROUP B OXYGEN UPTAKE SUBGROUPS[a]

T-1

Variable	Group	Mean	Standard Deviation	Comparison	F[b]
Weight (kg)	A	72.5	12	A > B	.60
	B	67.4	6		
$\dot{V}O_2$ (L/min)	A	3.41	0.56	A > B	.57
	B	3.15	0.40		
$\dot{V}O_2$ (ml/kg/min)	A	47.2	5	A > B	.02
	B	46.7	4		
$\dot{V}_E$ (L/min)	A	103	22	A > B	.01
	B	102	7		
Step Test Score	A	79	11	A > B	.16
	B	75	15		

[a]Group A, N = 4; Group B, N = 4.

[b]Least-squares F. $F_{.95}(1, 6) = 5.99$

TABLE 5-10

SUMMARY OF THE MEANS, STANDARD DEVIATIONS AND F'S FOR THE COMPARISONS BETWEEN GROUP A AND GROUP B OXYGEN UPTAKE SUBGROUPS[a]

T-2

Variable	Group	Mean	Standard Deviation	Comparison	F[b]
Weight (kg)	A	73.7	12	A > B	1.08
	B	66.7	5		
$\dot{V}O_2$ (L/min)	A	3.91	0.49	A > B	2.53
	B	3.43	0.34		
$\dot{V}O_2$ (ml/kg/min)	A	53.4	4	A > B	.76
	B	51.4	3		
$\dot{V}_E$ (L/min)	A	118	23	A > B	.94
	B	106	6		
Step Test Score	A	89	6	A > B	8.72*
	B	79	3		

*$p \leqq .05$ $F_{.95}(1, 6) = 5.99$

[a]Group A, N = 4; Group B, N = 4.

[b]Least-squares F.

TABLE 5-11

SUMMARY OF THE MEANS, STANDARD DEVIATIONS AND F'S FOR THE COMPARISONS BETWEEN GROUP A AND GROUP B OXYGEN UPTAKE SUBGROUPS[a]

T-3

Variable	Group	Mean	Standard Deviation	Comparison	F[b]
Weight (kg)	A	72.0	14	A > B	.23
	B	68.3	6		
$\dot{V}O_2$ (L/min)	A	3.98	0.96	A > B	.07
	B	3.84	0.44		
$\dot{V}O_2$ (ml/kg/min)	A	55.2	5	A < B	.15
	B	56.2	2		
$\dot{V}_E$ (L/min)	A	124	37	A > B	.02
	B	121	7		
Step Test Score	A	85	14	A < B	.03
	B	86	8		

[a]Group A, N = 4; Group B, N = 4.

[b]Least-squares F. $F_{.95}(1, 6) = 5.99$

TABLE 5-12

SUMMARY OF THE MEANS, STANDARD DEVIATIONS AND F'S FOR THE COMPARISONS OF GROUPS A AND B, COMBINED AT TEST ONE, WITH GROUP S[a]

Variable	Group	Mean	Standard Deviation	Comparison	F[b]
Age (yr)	A + B	18.4	1.0	AB < S	2.54
	S	18.9	1.2		
Height (in.)	A + B	70.9	3	AB < S	5.00*
	S	72.6	2		
Weight (lb.)	A + B	158	18	AB < S	13.76*
	S	177	13		
Heart Rate (b/min)	A + B	66	9	AB = S	.02
	S	66	11		
Adj. TS (msec)	A + B	385	11	AB < S	.03
	S	386	9		
Adj. EP (msec)	A + B	295	12	AB < S	.38
	S	297	10		
Adj. TP (msec)	A + B	91	9	AB > S	.35
	S	89	8		
Step Test Score	A + B	77	10	AB < S	33.91*
	S	94	8		

*$p \leq .05$ $F_{.95}(1, 49) = 4.04$

[a]Group A + B, N = 36; Group S, N = 15.

[b]Least-squares F.

TABLE 5-13

SUMMARY OF THE MEANS, STANDARD DEVIATIONS AND F'S FOR THE COMPARISONS OF SUBGROUPS A AND B, COMBINED AT TEST ONE, WITH GROUP S: OXYGEN UPTAKE DATA[a]

Variable	Group	Mean	Standard Deviation	Comparison	F[b]
Weight (kg)	A + B	69.9	9	AB < S	4.17
	S	79.5	7		
$\dot{V}O_2$ (L/min)	A + B	3.28	0.47	AB < S	13.74*
	S	4.46	0.68		
$\dot{V}O_2$ (ml/kg/min)	A + B	46.9	4	AB < S	11.39*
	S	56.0	6		
$\dot{V}_E$ (L/min)	A + B	103	15	AB < S	3.32
	S	125	29		
Adj. TS (msec)	A + B	390	12	AB > S	.15
	S	388	9		
Adj. EP (msec)	A + B	299	13	AB > S	.06
	S	298	7		
Adj. TP (msec)	A + B	91	5	AB > S	.07
	S	90	8		
Step Test Score	A + B	77	12	AB < S	4.45
	S	91	11		

*$p \leq .05$ $F_{.95}(1, 11) = 4.84$

[a]Group A + B, N = 8; Group S, N = 5.

[b]Least-squares F.

CHAPTER VI

DISCUSSION: PHYSICAL TRAINING STUDY

On the basis of the data presented in Chapter V, it is concluded that the tension period does not change as the level of physical condition varies. This is contrary to the findings of Raab (40, 41, 42, 43), Millahn (31), Emmrich and associates (15), and Klepzig (26). The preponderance of studies concerned with the contraction of cardiac muscle do not yield evidence that supports Raab's hypothesis.

The tension period is composed of the latent period and the isometric contraction period (55, 56). The latent period of a muscle begins with the depolarization of the plasma membrane and ends when the muscle exhibits an increase in tension.

In the normal left ventricle, the musculature is stimulated to contract by a wave of depolarization that travels, initially, through the left bundle branch and the Purkinje system. From the Purkinje system the depolarization wave travels along the plasma membranes of the ventricular myocardial cells. The plasma membrane is continuous with the sarcoplasmic reticulum and carries the depolarization wave down the T system of the Z line to the myofibrils deep in each myocardial cell (6, 39, 50). The terminus of the depolarization wave appears to be in the longitudinal component of the sarcoplasmic

reticulum. This component surrounds each sarcomere but is not continuous with other sarcomeres of the same myofibril.

As the depolarization wave travels across the plasma membrane and through the sarcoplasmic reticulum, calcium ions are allowed to cross the membranes into the cells and sarcomeres. Ringer (45) demonstrated that calcium ions are necessary for the frog heart to beat. Later research showed that in the absence of calcium ions, the rhythmic, spontaneous depolarization waves were still present (32). Heilbrunn (20) effectively demonstrated the necessity of intracellular calcium for the contraction of muscle tissue. The influx of calcium ions from the extracellular spaces facilitates excitation-contraction coupling (17) by acting directly on the chemo-mechanical mechanisms of contraction of the contractile proteins.

The length of the latent period may be varied somewhat by factors that change the rate of calcium flux into the cell or that change the time course of the calcium induced reactions that bring about contractions of the myofibrils. Certainly, temperature and the concentration of extracellular calcium would change the time course of the excitation process. However, there is no evidence that training reduces the body temperature and extracellular calcium of the resting individual. These conditions would be necessary to increase the latent period and, hence, tension period.

With the activation of the chemo-mechanical coupling, the second phase of the latent period begins. During this phase the myosin

molecules split ATP to derive energy for contraction. The outward manifestation of tension signifies the end of this phase.

In skeletal muscle, and probably cardiac tissue, there is a period of relaxation during the second phase of the latent period (47). This latency relaxation period corresponds to Hill's period of enhanced rigidity of skeletal muscle that occurs about halfway through the latent period (22). The length of this period decreases as the tissue pH increases. Again, there is no evidence that physical training reduces the pH of the tissues.

From the literature cited it is concluded that there is no reason to expect that conditioning should alter the duration of the latent period, and consequently, that part of the tension period that is the latent period.

The isometric interval of the left ventricle has been defined as the period between the closure of the mitral valve and the opening of the aortic semilunar valves (55). The interval is not truly isometric, as there is some shortening due to the bulging outward of non-muscular areas, such as the valves and valve rings, as pressure in the ventricle increases (16, 56). The shortening of many of the fibers continues throughout the interval, but the volume of blood in the ventricle remains the same.

The apparent changes in heart volume are actually changes in geometry. Besides the bulging of valves and the valve ring changes,

the atrioventricular diaphragm descends and the diameter, circumference and external length of the ventricle expand (46).

The changes in fiber length and geometry during the isometric phase are analogous to the series elastic component (SE) in the model skeletal muscle put forth by Hill (21). In this model the muscle consists of a contractile element (CE) and an elastic element in series with the contractile element. The SE, however, is not made up of one element, especially in the myocardium, nor are the elements necessarily placed at one or both ends of the contractile element. In the myocardium, there are SE components that are true SE elements and components that are not SE elements but behave like true SE elements. The various elements comprising the SE will be discussed later.

The importance of the SE as it relates to the duration of the isometric interval and TP lies in its mechanical properties. When a muscle contracts against a load the following sequence of events occurs: (A) the muscle is stimulated and the previously described events of the latent period run their course; (B) the CE begins to contract, but since it is working against a load the SE is stretched thereby keeping the overall muscle length the same; (C) as the CE continues to contract the SE becomes stiffer and tension increases over several milliseconds to the point at which it equals and exceeds the load; and (D) the CE continues to shorten, lifting the load while SE remains at a constant length (isotonic contraction). The more rigid the SE the shorter will be the duration of the isometric interval as described in B

above. The shorter the isometric period, the shorter will be TP, all other factors remaining constant.

In the myocardium, the SE element consists of the connective tissue at the origin and insertion of the muscle. As the muscle contracts this tissue is stretched in the manner typical of skeletal muscle. The more important SE elements are the apparent elements. The SE effect of the bulging valves and valve rings has been previously mentioned. At least two other elements exist. The first of these is the connective tissue between the layers of heart muscle. These layers, when stimulated, contract in oppostie directions producing a wringing effect (46). The layer of connective tissue is stretched during contraction and contributes to the SE component. However, unlike the other SE elements, this material is stretched throughout the contraction. The second element is the muscle tissue itself. Due to the asynchronous stimulation of the heart, the ventricle is not totally stimulated at one instant. Rather, a wave of depolarization travels around the ventricles, stimulating over a period of sixty to one hundred milliseconds. Since the latent period lasts about sixty milliseconds, part of the ventricular musculature will be in the process of contracting before the other parts have been stimulated. The unstimulated fibers are stretched by the contracting fibers, thus behaving as a SE. Since the mechanical event follows the depolarization wave at a constant interval (2), it would be expected that the duration of this stretching phase should equal the time course of the depolarization wave. However,

Hill (22) has found that the muscle becomes stiffer about halfway through the latent period. The degree of stiffness is equal to a force that is a large portion of the force the muscle can develop during an isometric twitch. Therefore, the SE function of the muscle tissue lasts about ten milliseconds.

The elasticity of the ventricle could be changed in the normal ventricle by decreasing or increasing the rate of transmission of the action potential through the myocardium. However the only factor that has any great effect on the conduction velocity is temperature (23). As previously mentioned, there is no evidence to show that physical training changes the resting body temperature. A decrease in body temperature would be necessary to bring about the conditions necessary to increase the duration of TP.

A second mechanism that could change the elasticity of the ventricle for a given beat or series of beats would be an increased load. That is, if the left ventricular end diastolic (LVED) volume were to increase, the tension on the SE would also increase. Assuming that diastolic pressure remains constant, the increased SE tension reduces the amount of tension that the CE must develop in order to cause ejection (24, 29, 48). If the rate of tension development (dp/dt) by the contractile element also remains constant, then the duration of the isometric interval will decrease. Conversely, a decrease in LVED volume should lead to an increase in the isometric interval, all other factors remaining constant.

Studies have shown that the cardiac output of athletes at rest is about the same as non-athletes (5). The lowering of heart rate by training is well known. Since the cardiac output is equal to heart rate times stroke volume, stroke volume must increase if heart rate decreases and cardiac output remains constant. The larger stroke volume of trained individuals is also well known (3). However, the origin of the increased stroke volume has not been decided. The two explanations are: (A) due to the decrease in heart rate the ventricle has more time to fill and be stretched by the increased volume of blood, and (B) the ventricle does not normally eject its total capacity with each beat. The increased stroke volume is due to increased ejection. The normal end diastolic left ventricular volume is approximately 150 to 160 milliliters and the average stroke volume for normal subjects is 70 to 75 milliliters (52). Also, the left ventricle hypertrophies with physical training, so the stretching of the musculature by even 150 to 160 milliliters of blood seems doubtful. However, data from this study show relatively high negative correlations (-.69 to -.91) between heart rate and the duration of the ejection period. Millhan (31) reports a similar finding (r = -.59). These data indicate that there is probably an increase in LVED volume as heart rate decreases. This increase is reflected in the increased ejection period. However, since these measures are quite indirect, further studies directed specifically at this problem and using more direct measures are needed.

If the LVED volume does increase as heart rate decreases, then TP will be shortened for the following reasons: (A) As the LVED volume increases, the tension on the SE component increases, thus reducing the LVED-aortic diastolic pressure difference. The stretching of the SE during diastole also reduces the amount of time that the CE must spend for this purpose during contraction. The time spent in stretching the SE is included in TP. (B) Secondly, it has been shown that the stretching of the muscle fibers increases dp/dt (48, 49). The combination of an increased dp/dt and time spent in stretching the SE, during which time tension development is relatively slow (21, 49), would decrease TP.

The remaining factor to be reviewed is the rate of tension development (dp/dt). Training has not been shown to change the diastolic blood pressure of normal persons (25). If the LVED volume remains constant along with the diastolic pressure, dp/dt must decrease if TP is to increase. The rate of tension development is increased by catecholamines (49) and decreased by acetylcholine (14) and decreased heart rate (1, 49). Increases in catecholamine concentration in the myocardium and in heart rate increase the rate of tension development, thus shortening the isometric contraction interval. The effect of heart rate on dp/dt, however, seems to appear only at high rates of stimulation (1). It is possible that an increase in sympathetic tone would increase dp/dt and thus reduce TP. Conversely, in light of the findings of DeGeest, Levy and associates (14), an

increase in the tonic activity of the vagus would decrease dp/dt and heart rate, thus increasing TP. These data support the contention that TP increases as fitness increases. However the data in this study do not support this theory.

The measurement of TP is made with the subject at rest. It is possible that the effects of increased vagal stimulation on the left ventricle are masked by the decreased heart rate or are too slight under physiologic conditions to be detected by the TP measure. The negative inotropic effects of the vagus have certainly been small enough to escape detection until recently (14). Secondly, while the positive inotropic effects of norepinephrine are quite strong, it is possible that unless the subject is in a state of high anxiety, the change in dp/dt may not be sufficient to be detected by TP measurement. It is generally assumed that students enter a period of increased anxiety at the end of each term. However, if this anxiety was present in the subjects it did not manifest itself in changes in TP either between tests or between groups at Test Three.

The results of the statistical analysis point up the stability of the tension period. Heart rate, age, respiratory phases and physical condition seem to have little effect on it. Therefore, if a valid use of TP should be discovered it seems unnecessary to adjust TP for heart rate or to measure an equal number of beats in each respiratory phase. The opposite is the case with total systole and ejection period. While neither of these changed significantly with the respiratory phases,

large changes occurred when they were adjusted for heart rate. Consequently any study using TS and EP should use heart rate adjusted values.

The comparisons of the oxygen uptake data with the Harvard Step Test Scores seemed to present a confused picture. The subgroup of Group A did not improve significantly in Step Test scores between tests. Its oxygen uptake values were not significantly different between tests. However, B's oxygen uptake group exhibited significant changes in oxygen uptake between tests while its Step Test scores did not change significantly.

Rank order correlations of oxygen uptake (ml/kg/min) and the Step Test Score produced a coefficient of .60. This coefficient is significant at the .05 level but is too low for predictive purposes. From these data it is hypothesized that the maximum oxygen uptake test used in this study did not yield accurate measurements of fitness. Figure 5-2 not only illustrates changes in heart rate and Step Test scores with fitness changes, but it also shows that there was a practice effect between tests for the oxygen uptake measures. Group A's values for oxygen uptake and ventilation improved between T-2 and T-3, while Step Test Scores and heart rate decreased. Group B's oxygen uptake (ml/kg/min) increased significantly between tests while the fitness of the Group did not increase significantly. Further studies in this area are needed to determine the sensitiveness of the

Step Test and maximum oxygen uptake test to changes in physical condition.

The failure of Group B to exhibit significant changes in physical condition may be attributed to either of two factors. First, the conditioning program may not have been as strenuous for the second group. Or, the subjects, on the average, improved up to the fitness level that a caloric expenditure of nine hundred and seventy-five kilocalories per hour could maintain. Since the Step Test scores attained by the two groups at the end of training were essentially the same, it is postulated that this is the maximum fitness level attainable, on the average, under the prevailing conditions of this training program.

Significant differences between the athletes and the non-athletes were to be expected, as they have been previously observed and reported (36). The fact that the athletes had significantly higher physical fitness scores than the non-athletes, while their tension periods were not significantly different again points up the stability of this measure.

CHAPTER VII

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purposes of this study were to determine the magnitude of the diurnal variation of the tension period and the effects of a vigorous training program on the duration of the tension period (TP) as measured by Blumberger (7). Raab has reviewed the literature concerning this measure and has concluded that TP increases in duration with increases in the fitness level of the individual (41).

Originally, fifty subjects were randomly assigned to either the Experimental (Group A) or Control (Group B). All subjects took the Harvard Step Test and had their tension periods measured. Five subjects from each group were also selected at random to take a maximum oxygen uptake test. Group A then trained for five weeks and was retested at the end of the training period. Group B did not train and was tested at the end of the Experimental's training period. The roles were then switched, with Group B training for five weeks and Group A detraining. The subjects were tested again at the end of the second training period. Thirty-six of the subjects completed the study. Only the data on subjects who completed all three tests were analyzed.

A group of fifteen athletes was tested once as an indicator of the effects of superior fitness on the variables under study (Group S). A random sample of five subjects was drawn from the Athlete Group. This subgroup took the maximum oxygen uptake test taken by the other two subgroups.

A group of nine graduate student volunteers participated in the diurnal variation study. These subjects reported for tension period measurements at four different times during the day. The first test was made in the post-absorptive state early in the morning. For the subsequent tests the subjects were asked to refrain from consuming caffeine or other stimulants, and to forego the use of tobacco.

Within-group and between-group comparisons between tests were made using the least-squares analysis of variance. All variables in the groups were intercorrelated.

The tension period did not change with the level of physical fitness as measured by either the Harvard Step Test or maximum oxygen uptake. Furthermore, TP did not correlate significantly with either of the fitness tests. There were no significant differences between the tension periods of athletes and non-athletes.

Analysis of the diurnal variation data showed that, while the post-absorptive measures were higher than subsequent measures, there was no significant difference between the values obtained at each test.

Conclusions

The data warrant the following conclusions:

1. Tension period, as measured in this study, does not change with the level of fitness of the individual.

2. Tension period does not differentiate between various fitness groups.

3. Tension period is not affected by time of day or meals, when tobacco and caffeine are not used or consumed.

4. Tension period is not significantly affected by individual changes in heart rate.

Recommendations

The results of this study are clear, but limited to a relatively small group of people. Additional studies using several groups of experimental and control subjects at different age levels would elucidate the question of the effects of age versus the effects of training on TP.

Until such studies are conducted, the use of TP as an indicator of fitness is questionable. The data in this study suggest that the best way to determine the ability of a subject to withstand exercise stress is to place the subject under such a stress.

APPENDIX

Variables for Tables A-1 Through A-11

No.

1. Mean of Raw Heart Rates (10 readings) B/M--HR.
2. Mean of Raw TS (10 readings)--Milliseconds--TS.
3. Mean of Raw EP (10 readings)--Milliseconds--EP.
4. Mean of Raw TP (10 readings)--Milliseconds--TP.
5. Mean of Heart Rate Adjusted TS (10 readings)--Milliseconds--TSA.
6. Mean of Heart Rate Adjusted EP (10 readings)--Milliseconds--EPA.
7. Mean of Heart Rate Adjusted TP (10 readings)--Milliseconds--TPA.
8. Mean Heart Rate During Inspiration (5 readings) B/M--HRI.
9. Mean Heart Rate Adjusted TS During Inspiration (5 readings)--Milliseconds--TSI.
10. Mean Heart Rate Adjusted EP During Inspiration (5 readings)--Milliseconds--EPI.
11. Mean Heart Rate Adjusted TP During Inspiration (5 readings)--Milliseconds--TPI.
12. Mean Heart Rate During Expiration (5 readings) B/M--HRE.
13. Mean Heart Rate Adjusted TS During Expiration (5 readings)--Milliseconds--TSE.
14. Mean Heart Rate Adjusted EP During Expiration (5 readings)--Milliseconds--EPE.
15. Mean Heart Rate Adjusted TP During Expiration (5 readings)--Milliseconds--TPE.
16. Height in Inches--Ht.

No.

17. Weight in Pounds--Wt.

18. Harvard Step Test Score--HST.

19. Age

TABLE A-1

DIURNAL VARIATION GROUP: INTERCORRELATION MATRIX FOR THE SIXTEEN VARIABLES MEASURED AT TEST ONE

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	19
HR	1	1.00															
TS	2	-.75	1.00														
EP	3	-.65	.95	1.00													
TP	4	-.72	.90	.71	1.00												
TSA	5	-.36	.89	.89	.76	1.00											
EPA	6	-.15	.71	.85	.43	.91	1.00										
TPA	7	-.52	.83	.64	.97	.80	.48	1.00									
HRI	8	.93	-.53	-.41	-.55	-.10	.11	-.33	1.00								
TSI	9	-.42	.91	.90	.78	.99	.88	.81	-.14	1.00							
EPI	10	-.27	.81	.90	.58	.95	.97	.61	-.02	.94	1.00						
TPI	11	-.55	.78	.61	.88	.71	.42	.90	-.34	.77	.50	1.00					
HRE	12	.96	-.86	-.75	-.84	-.53	-.30	-.68	.81	-.60	-.43	-.70	1.00				
TSE	13	-.25	.81	.84	.68	.98	.91	.75	-.02	.93	.95	.59	-.41	1.00			
EPE	14	.03	.50	.71	.15	.73	.94	.20	.26	.70	.84	.21	-.09	.76	1.00		
TPE	15	-.40	.72	.55	.88	.75	.44	.93	-.28	.70	.60	.68	-.54	.75	.14	1.00	
AGE	19	.73	-.47	-.43	-.41	-.16	-.06	-.24	.56	-.25	-.09	-.42	.71	-.03	-.02	-.01	1.00

$r_{.975} = .67$

$N = 9$

TABLE A-2

DIURNAL VARIATION GROUP: INTERCORRELATION MATRIX FOR THE SIXTEEN VARIABLES MEASURED AT TEST TWO

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	19
HR	1	1.00															
TS	2	-.78	1.00														
EP	3	-.82	.90	1.00													
TP	4	-.48	.82	.50	1.00												
TSA	5	-.33	.85	.67	.83	1.00											
EPA	6	-.33	.70	.81	.35	.78	1.00										
TPA	7	-.13	.60	.22	.93	.80	.25	1.00									
HRI	8	.98	-.71	-.77	-.40	-.24	-.26	-.04	1.00								
TSI	9	-.33	.84	.64	.85	.99	.73	.82	-.21	1.00							
EPI	10	-.41	.73	.85	.36	.75	.98	.23	-.35	.71	1.00						
TPI	11	-.20	.58	.19	.93	.71	.13	.97	-.10	.76	.11	1.00					
HRE	12	.97	-.83	-.86	-.52	-.43	-.43	-.19	.91	-.45	-.51	-.26	1.00				
TSE	13	-.32	.83	.67	.79	.98	.80	.75	-.25	.94	.78	.64	-.38	1.00			
EPE	14	-.36	.69	.80	.34	.74	.94	.24	-.31	.69	.88	.14	-.43	.77	1.00		
TPE	15	-.15	.63	.30	.88	.82	.36	.92	-.80	.79	.37	.84	-.19	.82	.26	1.00	
AGE	19	.44	.05	-.12	.27	.45	.28	.18	.41	.37	.17	.35	.45	.33	.30	.52	1.00

$r_{.975} = .67$

$N = 9$

TABLE A-3

DIURNAL VARIATION GROUP: INTERCORRELATION MATRIX FOR THE SIXTEEN VARIABLES MEASURED AT TEST THREE

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	19
HR	1	1.00															
TS	2	-.70	1.00														
EP	3	-.75	.77	1.00													
TP	4	-.09	.54	-.11	1.00												
TSA	5	-.04	.69	.32	.65	1.00											
EPA	6	-.26	.55	.83	-.23	.52	1.00										
TPA	7	.25	.31	-.35	.94	.67	-.29	1.00									
HRI	8	.88	-.71	-.81	-.04	-.10	-.43	.26	1.00								
TSI	9	-.11	.78	.45	.62	.97	.58	.59	-.21	1.00							
EPI	10	-.54	.66	.91	-.18	.38	.89	.34	-.52	.51	1.00						
TPI	11	.36	.30	-.28	.84	.77	-.10	.94	.24	.69	-.27	1.00					
HRE	12	.96	-.63	-.66	-.12	.10	-.15	.21	.72	-.06	-.51	.39	1.00				
TSE	13	.34	.40	-.04	.59	.90	.34	.71	.17	.77	.08	.80	.38	1.00			
EPE	14	.28	.11	.35	-.27	.46	.74	-.15	-.09	.40	.36	.15	46	.52	1.00		
TPE	15	.04	.20	-.40	.84	.30	-.55	.82	.27	.25	-.37	.59	-.10	.32	-.63	1.00	
AGE	19	.60	-.02	-.34	.44	.57	-.00	.65	.68	.44	-.11	.62	.47	.75	.14	.51	1.00

$r_{.975} = .67$

$N = 9$

TABLE A-4

DIURNAL VARIATION GROUP: INTERCORRELATION MATRIX FOR THE SIXTEEN VARIABLES MEASURED AT TEST FOUR

$r_{.975} = .67$

N = 9

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	19
HR	1	1.00															
TS	2	-.49	1.00														
EP	3	-.47	.87	1.00													
TP	4	-.27	.75	.32	1.00												
TSA	5	.38	.62	.50	.55	1.00											
EPA	6	.39	.46	.63	.09	.85	1.00										
TPA	7	.21	.49	.04	.88	.70	.22	1.00									
HRI	8	.99	-.46	-.46	-.23	.40	.39	.24	1.00								
TSI	9	.39	.60	.50	.51	.99	.86	.67	.42	1.00							
EPI	10	.44	.34	.56	-.05	.77	.98	.11	.46	.79	1.00						
TPI	11	.10	.54	.09	.90	.66	.17	.97	.14	.65	.05	1.00					
HRE	12	.99	-.50	-.48	-.29	.36	.38	.18	.97	.36	.43	.07	1.00				
TSE	13	.38	.62	.47	.58	.99	.82	.72	.39	.97	.73	.67	.36	1.00			
EPE	14	.32	.58	.67	.24	.90	.98	.34	.32	.90	.91	.32	.31	.88	1.00		
TPE	15	.32	.45	.05	.80	.76	.33	.96	.33	.71	.24	.87	.30	.80	.42	1.00	
AGE	19	.56	-.15	-.13	-.09	.33	.33	.18	.49	.32	.33	.08	.62	.35	.34	.24	1.00

TABLE A-5

GROUP A: INTERCORRELATION MATRIX FOR THE NINETEEN VARIABLES MEASURED AT TEST ONE

$r_{.975} = .44$

N = 20

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
HR	1	1.00																		
TS	2	-.79	1.00																	
EP	3	-.72	.83	1.00																
TP	4	-.17	.37	-.21	1.00															
TSA	5	-.33	.84	.64	.42	1.00														
EPA	6	-.20	.52	.82	-.45	.62	1.00													
TPA	7	-.17	.35	-.22	1.00	.40	-.47	1.00												
HRI	8	.97	-.75	-.70	-.13	-.30	-.20	-.12	1.00											
TSI	9	-.38	.85	.62	.46	.96	.56	.44	-.29	1.00										
EPI	10	-.25	.58	.82	-.36	.66	.96	-.38	-.20	.65	1.00									
TPI	11	-.19	.38	-.19	.99	.43	-.43	.99	-.14	.47	-.36	1.00								
HRE	12	.98	-.81	-.71	-.21	-.38	-.20	-.21	.91	-.45	-.29	-.23	1.00							
TSE	13	-.25	.76	.61	.33	.96	.65	.31	-.27	.85	.61	-.34	-.24	1.00						
EPE	14	-.12	.42	.74	-.50	.55	.96	-.52	-.17	.43	.85	-.46	-.08	.64	1.00					
TPE	15	-.13	.31	-.26	.99	.37	-.49	.99	-.09	.40	-.38	.95	-.17	.29	-.55	1.00				
Ht.	16	.18	.04	-.26	.50	.25	-.19	.50	.16	.20	-.21	.49	.18	.27	-.16	.50	1.00			
Wt.	17	.01	.46	.27	.36	.72	.40	.34	.06	.71	.42	.38	-.06	.68	.35	.30	.43	1.00		
HST	18	-.49	.28	.30	-.02	-.03	.00	-.02	-.40	.10	.08	.02	-.54	-.16	-.09	-.06	-.18	-.11	1.00	
Age	19	-.08	.28	.23	.11	.35	.24	.10	-.05	.34	.25	.10	-.13	.35	.23	.08	.10	.46	-.21	1.00

TABLE A-6

GROUP A: INTERCORRELATION MATRIX FOR THE NINETEEN VARIABLES MEASURED AT TEST TWO

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
HR	1	1.00																		
TS	2	-.67	1.00										$r_{.975} = .44$							
EP	3	-.69	.85	1.00									N = 20							
TP	4	-.25	.63	.13	1.00															
TSA	5	-.08	.79	.56	.66	1.00														
EPA	6	.10	.46	.65	-.08	.69	1.00													
TPA	7	-.23	.62	.11	1.00	.66	-.09	1.00												
HRI	8	.99	-.69	-.70	-.28	-.11	.09	-.26	1.00											
TSI	9	-.12	.80	.60	.62	.99	.72	.62	-.13	1.00										
EPI	10	.06	.50	.66	-.03	.72	.98	-.04	.06	.75	1.00									
TPI	11	-.24	.66	.18	.98	.71	.00	.98	-.26	.69	.04	1.00								
HRE	12	.99	-.69	-.72	-.23	-.11	.04	-.21	.97	-.15	.00	-.21	1.00							
TSE	13	-.06	.77	.53	.68	.99	.66	.67	-.10	.97	.68	.72	-.08	1.00						
EPE	14	.15	.40	.60	-.14	.64	.98	-.15	.13	.66	.94	-.04	.10	.62	1.00					
TPE	15	-.23	.57	.06	.99	.60	-.16	.99	-.26	.55	-.09	.93	-.21	.62	-.22	1.00				
Ht.	16	.27	.16	-.07	.40	.45	.20	.40	.26	.45	.20	.46	.26	.43	.18	.34	1.00			
Wt.	17	.18	.25	.14	.27	.50	.40	.28	.20	.51	.38	.36	.15	.48	.40	.20	.46	1.00		
HST	18	-.24	-.03	-.04	.00	-.23	-.31	.00	-.20	-.24	-.33	.00	-.24	-.22	-.28	.00	-.12	.01	1.00	
Age	19	.18	.03	-.08	.17	.20	.09	.19	.19	.18	.06	.21	.19	.21	.11	.15	.10	.50	-.11	1.00

TABLE A-7

GROUP A: INTERCORRELATION MATRIX FOR THE NINETEEN VARIABLES MEASURED AT TEST THREE

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
HR	1	1.00																		
TS	2	-.77	1.00										$r_{.975} = .44$							
EP	3	-.83	.95	1.00									N = 20							
TP	4	-.34	.72	.48	1.00															
TSA	5	-.32	.85	.73	.79	1.00														
EPA	6	-.22	.73	.72	.44	.89	1.00													
TPS	7	-.34	.73	.49	1.00	.80	.45	1.00												
HRI	8	.99	-.77	-.84	-.32	-.33	-.25	-.32	1.00											
TSI	9	-.38	.83	.76	.77	.99	.89	.78	-.37	1.00										
EPI	10	-.32	.76	.78	.41	.87	.98	.43	-.33	.89	1.00									
TPI	11	-.32	.72	.48	.97	.80	.46	.97	-.28	.81	.44	1.00								
HRE	12	.99	-.77	-.82	-.35	-.33	-.22	-.35	.96	-.39	-.32	-.34	1.00							
TSE	13	-.26	.80	.67	.79	.98	.87	.80	-.29	.94	.83	.77	-.24	1.00						
EPE	14	-.16	.68	.67	.43	.88	.98	.45	-.20	.85	.94	.45	-.13	.89	1.00					
TPE	15	-.30	.69	.44	.98	.77	.43	.98	-.30	.73	.39	.91	-.29	.80	.43	1.00				
Ht.	16	.22	.04	-.08	.27	.25	.15	.28	.25	.26	.14	.32	.21	.22	.17	.22	1.00			
Wt.	17	.00	.22	.19	.19	.31	.30	.21	-.05	.35	.34	.24	-.01	.25	.28	.13	.49	1.00		
HST	18	-.23	.05	.11	-.08	-.11	-.12	-.09	-.25	-.08	-.07	-.07	-.21	-.15	-.16	-.07	-.30	.07	1.00	
Age	19	.00	.23	.21	.16	.32	.35	.20	-.03	.33	.37	.18	.01	.32	.35	.16	.10	.47	-.13	1.00

TABLE A-8

GROUP B: INTERCORRELATION MATRIX FOR THE NINETEEN VARIABLES MEASURED AT TEST ONE

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
HR	1	1.00																		
TS	2	-.82	1.00										$r_{.975} = .50$							
EP	3	-.82	.88	1.00									N = 16							
TP	4	.24	-.05	-.52	1.00															
TSA	5	-.23	.74	.55	.17	1.00														
EPA	6	-.28	.63	.84	-.64	.65	1.00													
TPA	7	.25	-.06	-.53	1.00	.16	-.65	1.00												
HRI	8	.97	-.75	-.74	.21	-.12	-.28	.22	1.00											
TSI	9	-.28	.75	.61	.07	.96	.70	.05	-.13	1.00										
EPI	10	-.44	.70	.87	-.55	.70	.98	-.57	-.32	.78	1.00									
TPI	11	.32	-.11	-.57	.98	.17	-.63	.98	.32	.08	-.55	1.00								
HRE	12	.98	-.85	-.83	.23	-.29	-.42	.24	.92	-.37	-.50	.30	1.00							
TSE	13	-.16	.65	.41	.30	.92	.49	.29	-.13	.78	.49	.26	-.16	1.00						
EPE	14	-.28	.51	.77	-.68	.57	.96	-.68	-.23	.57	.89	-.66	-.29	.48	1.00					
TPE	15	.17	.00	-.48	.98	.16	-.63	.98	.13	.04	-.54	.93	.17	.32	-.67	1.00				
Ht.	16	-.22	.29	.23	.01	.24	.16	.03	-.31	.09	.13	-.08	-.16	.42	.22	.12	1.00			
Wt.	17	-.23	.30	.14	.23	.23	-.01	.25	-.31	.08	-.03	.17	-.17	.44	.07	.30	.81	1.00		
HST	18	.18	-.09	-.20	.25	.02	-.20	.28	.10	-.14	-.28	.26	.21	.23	-.06	.28	.23	.38	1.00	
Age	19	-.09	.31	.41	-.32	.41	.56	-.32	-.12	.38	.50	-.30	-.06	.39	.61	-.33	.08	.08	.03	1.00

TABLE A-9

GROUP B: INTERCORRELATION MATRIX FOR THE NINETEEN VARIABLES MEASURED AT TEST TWO

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
HR	1	1.00																		
TS	2	-.64	1.00										$r_{.975} = .50$							
EP	3	-.70	.81	1.00									N = 16							
TP	4	.05	.34	-.28	1.00															
TSA	5	.16	.66	.33	.52	1.00														
EPA	6	.13	.44	.61	-.30	.66	1.00													
TPA	7	.08	.33	-.28	1.00	.53	-.28	1.00												
HRI	8	.97	-.62	-.65	.00	.15	.16	.02	1.00											
TSI	9	.09	.69	.40	.46	.97	.68	.47	.13	1.00										
EPI	10	.04	.47	.67	-.33	.61	.97	-.32	.12	.67	1.00									
TPI	11	.09	.35	-.25	.98	.57	-.22	.97	.06	.54	-.26	1.00								
HRE	12	.98	-.63	-.72	.10	.15	.08	.12	.90	.05	-.04	.12	1.00							
TSE	13	.23	.58	.24	.54	.97	.61	.56	.17	.89	.52	.56	.25	1.00						
EPE	14	.20	.39	.55	-.27	.67	.98	-.24	.19	.65	.92	-.19	.17	.65	1.00					
TPE	15	.05	.31	-.29	.98	.48	-.33	.98	-.01	.40	-.36	.92	.11	.53	-.29	1.00				
Ht.	16	-.07	.13	-.02	.24	.10	-.07	.23	-.13	.09	-.12	.24	-.03	.13	-.03	.19	1.00			
Wt.	17	-.15	.08	-.07	.25	-.04	-.23	.23	-.22	-.06	-.29	.24	-.10	.00	-.17	.19	.83	1.00		
HST	18	-.06	.16	-.03	.32	.14	-.09	.32	-.15	.06	-.19	.28	.00	.24	-.01	.31	.58	.60	1.00	
Age	19	.13	.08	-.31	-.40	.19	.56	-.37	.14	.15	.52	-.39	.08	.23	.57	-.35	.10	.04	.38	1.00

TABLE A-10

GROUP B: INTERCORRELATION MATRIX FOR THE NINETEEN VARIABLES MEASURED AT TEST THREE

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
HR	1	1.00																		
TS	2	-.65	1.00										$r_{.975} = .50$							
EP	3	-.59	.88	1.00									N = 16							
TP	4	-.09	.20	-.29	1.00															
TSA	5	-.10	.82	.72	.19	1.00														
EPA	6	.02	.61	.79	-.39	.82	1.00													
TPA	7	-.21	.39	-.08	.95	.34	-.26	1.00												
HRI	8	.98	-.65	-.58	-.11	-.12	.01	.22	1.00											
TSI	9	-.09	.80	.71	.15	.98	.82	.30	-.07	1.00										
EPI	10	-.01	.62	.79	-.39	.81	.99	-.26	.01	.83	1.00									
TPI	11	-.16	.34	-.12	.92	.32	-.27	.97	-.15	.30	-.27	1.00								
HRE	12	.97	-.61	-.58	-.02	-.07	.02	-.15	.91	-.09	-.03	-.11	1.00							
TSE	13	-.12	.82	.69	.24	.98	.77	.38	-.17	.92	.75	.34	-.05	1.00						
EPE	14	.02	.61	.77	-.37	.81	.99	-.25	-.01	.79	.95	-.26	.04	.79	1.00					
TPE	15	-.25	.41	-.05	.93	.34	-.25	.98	-.28	.29	-.24	.91	-.17	.40	-.24	1.00				
Ht.	16	-.08	.32	.17	.31	.36	.19	.28	-.07	.32	.15	.30	-.06	.37	-.24	.22	1.00			
Wt.	17	-.04	.30	.05	.49	.35	.06	.50	-.06	.29	-.02	.56	.01	.39	.13	.41	.81	1.00		
HST	18	-.04	.15	.09	.26	.16	.06	.21	-.13	.10	.02	.16	.07	.22	.10	.20	-.10	.12	1.00	
Age	19	.07	.04	-.09	.26	.11	-.05	.26	.15	.13	.01	.20	.02	.09	-.08	.27	-.04	-.10	-.22	1.00

TABLE A-11

GROUP S: INTERCORRELATION MATRIX FOR THE NINETEEN VARIABLES MEASURED AT TEST ONE

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
HR	1	1.00																		
TS	2	-.85	1.00										$r_{.975} = .51$							
EP	3	-.91	.92	1.00									N = 15							
TP	4	.48	-.18	-.54	1.00															
TSA	5	-.18	.68	.45	.33	1.00														
EPA	6	-.58	.80	.87	-.48	.67	1.00													
TPA	7	.48	-.19	-.55	1.00	.31	-.49	1.00												
HRI	8	.99	-.83	-.89	.45	-.17	-.55	.45	1.00											
TSI	9	-.17	.66	.46	.27	.98	.70	.26	-.14	1.00										
EPI	10	-.50	.73	.81	-.48	.66	.99	-.49	-.47	.70	1.00									
TPI	11	.47	-.22	-.56	.98	.25	-.53	.98	.46	.21	-.54	1.00								
HRE	12	.99	-.84	-.91	.51	-.18	-.60	.50	.97	-.18	-.52	.48	1.00							
TSE	13	-.22	.70	.46	.34	.97	.64	.32	.22	.92	.61	.25	-.20	1.00						
EPE	14	-.62	.83	.88	-.44	.68	.97	-.45	-.59	.67	.93	-.47	-.63	.68	1.00					
TPE	15	.50	-.15	-.51	.98	.40	-.39	.96	.45	.33	-.38	.90	.53	.43	-.37	1.00				
Ht.	16	-.41	.58	.46	.10	.51	.41	.10	-.41	.51	.40	.05	-.42	.46	.36	.13	1.00			
Wt.	17	-.29	.45	.30	.23	.41	.22	.23	-.31	.37	.20	.16	-.29	.43	.20	.29	.57	1.00		
HST	18	-.60	.64	.67	-.31	.36	.59	-.32	-.56	.38	.55	-.31	-.62	.32	.60	-.33	.31	.09	1.00	
Age	19	.33	-.40	-.35	.02	-.28	-.29	.01	.34	-.28	-.25	-.01	.32	-.28	-.33	.04	.01	-.04	-.23	1.00

Variables for Tables A-12 Through A-18

No.

1. Maximum Oxygen Uptake--L/min--VOL.
2. Maximum Oxygen Uptake--ml/kg/min--VOKG.
3. Ventilation at Maximum Oxygen Uptake--L/min--VE.
4. Weight--kilograms--Wt.
5. Maximum Oxygen Uptake at Constant Work Level for Three Tests--L/min--CWLVOL.
6. Maximum Oxygen Uptake at Constant Work Level for Three Tests--ml/kg/min--CWLVOKG.
7. Ventilation at Constant Work Level for Three Tests--L/min--CWLVE.
8. Resting Heart Rate--b/min--HR.
9. TS--Average 10 Beats for EKG Tests--milliseconds--TSA.
10. EP--Average 10 Beats for EKG Tests--milliseconds--EPA.
11. TP--Average 10 Beats for EKG Tests--milliseconds--TPA.
12. Harvard Step Test Score--HST.

TABLE A-12

GROUP A: INTERCORRELATION MATRIX FOR THE OXYGEN UPTAKE VARIABLES MEASURED AT TEST ONE

Variable		1	2	3	4	5	6	7	8	9	10	11	12
VOL	1	1.00											
VOKG	2	.34	1.00					$r_{.975} = .95$					
VE	3	.84	.64	1.00				N = 4					
Wt	4	.81	-.27	.48	1.00								
CWLVOL	5	.96	.14	.67	.90	1.00							
CWLVOKG	6	.60	.84	.59	.08	.51	1.00						
CWLVE	7	1.00	.28	.83	.85	.97	.54	1.00					
HR	8	.43	-.25	.51	.62	.36	-.37	.48	1.00				
TSA	9	.32	-.66	-.22	.73	.56	-.16	.36	.12	1.00			
EPA	10	.12	-.85	-.36	.65	.37	-.43	.18	.22	.96	1.00		
TPA	11	.73	.47	.45	.44	.77	.87	.69	-.30	.34	.06	1.00	
HST	12	.27	.55	.08	-.09	.31	.85	.22	-.75	.08	-.17	.85	1.00

TABLE A-13

GROUP A: INTERCORRELATION MATRIX FOR THE OXYGEN UPTAKE VARIABLES MEASURED AT TEST TWO

Variable		1	2	3	4	5	6	7	8	9	10	11	12
VOL	1	1.00											
VOKG	2	-.37	1.00										
VE	3	.88	-.63	1.00									
Wt	4	.92	-.70	.95	1.00								
CWLVOL	5	.92	-.07	.80	.74	1.00							
CWLVOKG	6	-.22	.93	-.39	-.55	.15	1.00						
CWLVE	7	.87	-.70	1.00	.97	.75	-.47	1.00					
HR	8	.91	-.72	.95	1.00	.72	-.57	.97	1.00				
TSA	9	.88	-.74	.87	.98	.64	-.66	.91	.98	1.00			
EPA	10	.78	-.51	.58	.79	.50	-.58	.62	.80	.89	1.00		
TPA	11	.34	-.64	.74	.56	.35	-.33	.73	.55	.43	-.04	1.00	
HST	12	.44	.61	.23	.10	.74	.78	.14	.06	-.04	-.05	-.04	1.00

$r_{.975} = .95$

N = 4

TABLE A-14

GROUP A: INTERCORRELATION MATRIX FOR THE OXYGEN UPTAKE VARIABLES MEASURED AT TEST THREE

Variable		1	2	3	4	5	6	7	8	9	10	11	12
VOL	1	1.00											
VOKG	2	.58	1.00					$r_{.975} = .95$					
VE	3	1.00	.51	1.00				N = 4					
Wt	4	.94	.26	.96	1.00								
CWLVOL	5	.43	.91	.37	.13	1.00							
CWLVOKG	6	-.55	.34	-.61	-.79	.50	1.00						
CWLVE	7	.69	.84	.65	.48	.92	.15	1.00					
HR	8	.13	-.71	.21	.46	-.81	-.90	-.52	1.00				
TSA	9	.87	.76	.85	.72	.78	-.15	.95	-.26	1.00			
EPA	10	.72	.79	.69	.53	.88	.08	1.00	-.45	.97	1.00		
TPA	11	1.00	.59	1.00	.94	.43	-.55	.69	.13	.87	.71	1.00	
HST	12	-.12	.67	-.19	-.42	.84	.88	.59	-.98	.33	.54	-.12	1.00

TABLE A-15

GROUP B: INTERCORRELATION MATRIX FOR THE OXYGEN UPTAKE VARIABLES MEASURED AT TEST ONE

Variable		1	2	3	4	5	6	7	8	9	10	11	12
VOL	1	1.00											
VOKG	2	.69	1.00					$r_{.975} = .95$					
VE	3	.70	.60	1.00				$N = 4$					
Wt	4	.82	.14	.44	1.00								
CWLVOL	5	.91	.51	.35	.86	1.00							
CWLVOKG	6	.25	.73	-.11	-.19	.35	1.00						
CWLVE	7	.11	.66	.61	-.41	-.25	.29	1.00					
HR	8	-.90	-.62	-.33	-.76	-.99	-.49	.15	1.00				
TSA	9	.77	.85	.93	.34	.46	.25	.71	-.50	1.00			
EPA	10	.76	.87	.92	.31	.45	.29	.73	-.49	1.00	1.00		
TPA	11	-.70	-.85	-.92	-.25	-.37	-.27	-.77	.42	-.99	-1.00	1.00	
HST	12	-.62	-.62	-.99	-.31	-.24	.08	-.71	.24	-.94	.92	.94	1.00

TABLE A-16

GROUP B: INTERCORRELATION MATRIX FOR THE OXYGEN UPTAKE VARIABLES MEASURED AT TEST TWO

Variable		1	2	3	4	5	6	7	8	9	10	11	12
VOL	1	1.00											
VOKG	2	.69	1.00										
VE	3	.12	.77	1.00									
Wt	4	.89	.28	-.35	1.00								
CWLVOL	5	.97	.70	.09	.84	1.00							
CWLVOKG	6	.46	.88	.68	.06	.59	1.00						
CWLVE	7	-.04	.68	.89	-.49	.04	.82	1.00					
HR	8	.04	.21	.78	-.84	-.55	.24	.75	1.00				
TSA	9	-.52	-.55	-.23	-.12	-.55	-.85	-.55	.10	1.00			
EPA	10	-.34	.14	.58	-.36	-.39	-.19	.23	.69	.66	1.00		
TPA	11	-.18	-.56	-.92	.41	.14	-.35	-.69	-.84	-.16	-.85	1.00	
HST	12	.03	.80	.26	.62	.94	.81	.33	-.34	-.80	-.46	.05	1.00

$r_{.975} = .95$

N = 4

TABLE A-17

GROUP B: INTERCORRELATION MATRIX FOR THE OXYGEN UPTAKE VARIABLES MEASURED AT TEST THREE

Variable		1	2	3	4	5	6	7	8	9	10	11	12
VOL	1	1.00											
VOKG	2	.64	1.00										
VE	3	.79	.97	1.00									
Wt	4	.94	.33	.53	1.00								
CWLVOL	5	.72	.54	.59	.67	1.00							
CWLVOKG	6	-.48	.15	-.05	-.63	.16	1.00						
CWLVE	7	.64	.96	.93	.36	.72	.29	1.00					
HR	8	-.97	-.47	-.66	-.97	-.60	.66	-.45	1.00				
TSA	9	.55	.57	.65	.38	-.12	-.60	.35	-.57	1.00			
EPA	10	.32	.52	.55	.12	-.31	-.46	.27	-.33	.96	1.00		
TPA	11	.89	.26	.45	.98	.74	-.53	.34	-.92	.21	-.05	1.00	
HST	12	.72	.64	.68	.63	.99	.21	.81	-.59	-.04	-.22	.69	1.00

$r_{.975} = .95$

N = 4

TABLE A-18

GROUP S: INTERCORRELATION MATRIX FOR THE OXYGEN UPTAKE VARIABLES MEASURED AT TEST ONE

Variable		1	2	3	4	8	9	10	11	12
VOL	1	1.00								
VOKG	2	.86	1.00				$r_{.975} = .88$			
VE	3	.80	.86	1.00			N = 5			
Wt	4	.76	.32	.39	1.00					
HR	8	-.63	-.84	-.52	-.09	1.00				
TSA	9	.38	-.06	-.22	.76	.05	1.00			
EPA	10	.87	.84	.53	.54	-.84	.43	1.00		
TPA	11	-.32	-.73	-.66	.34	.73	.69	-.35	1.00	
HST	12	.23	.39	-.13	-.08	-.75	.26	.67	-.26	1.00

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