AN ABSTRACT OF THE THESIS OF

Frank Goulard for the degree of Master of Science in Education presented on August 5, 1981

Title: QT INTERVAL CHANGES DURING MONITORED EXERTION FOLLOWING VARIED CARBOHYDRATE FEEDINGS AND VITAMIN B-6 SUPPLEMENTATION IN HUMANS

Abstract approved: Redacted for Privacy
(Donald E. Campbell)

The purpose of this study was: 1) to compare the change in QT interval values before, during, and after exercise following carbohydrate depletion and loading, and 2) to assess the change following vitamin B-6 supplementation. ECG monitoring devices and bicycle ergometers were used to collect ECG tracings and control the workload of four male bicyclists.

A two-way analysis of variance indicated that a QT value difference from a resting to an exercise state was smaller ($p < .05$) than the control at the three work intensities which followed depletion diets. The analysis of variance further indicated that a QT value difference from a resting to an exercise state was smaller ($p < .05$) than the control at the final work intensity level, 90% of maximal heart rate (MHR), which followed loading diets. Pairwise contrasts of QT value increases between resting and exercise states when comparing two levels of vitamin B-6 intake (2 mg, 10 mg) showed that QT value increases were

greater ($p < .05$) with the higher level of vitamin B-6 at the beginning work intensity level, 60% of MHR, following both the depletion and loading diets.

Results of the study established that a low percentage of dietary carbohydrates was unfavorable for the cardiac and QT interval demands of exercise stress at all three of the work intensities. A high percentage of dietary carbohydrates was unfavorable only at an anaerobic work intensity of 90% of MHR. In addition, the study showed that the QT interval response to exercise at an aerobic work intensity of 60% of MHR was more favorable with a higher vitamin B-6 intake.

QT Interval Changes During Monitored Exertion Following Varied Carbohydrate Feedings and Vitamin B-6 Supplementation in Humans

by

Frank Goulard

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed August 5, 1981

Commencement June 1982

APPROVED:

Redacted for Privacy

Professor of Physical Education

Redacted for Privacy

Coordinator of Teaching Specialties

Redacted for Privacy

Dean of Graduate School

Date thesis is presented August 5, 1981

Typed by Nancy Lindsey for Frank Goulard

ACKNOWLEDGEMENT

I thank God for making this thesis a true labor of love. Dr. Donald E. Campbell has been especially encouraging and supportive in all my efforts. Funds for this study were made available through a grant from the Oregon Agricultural Experiment Station and Dr. James E. Leklem. Finally, this thesis is dedicated to my father who set a model example for me to discover new worlds and my mother who gave me her desire to pursue dreams and not to give up on them.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

QT INTERVAL CHANGES DURING MONITORED EXERTION FOLLOWING VARIED CARBOHYDRATE FEEDINGS AND VITAMIN B-6 SUPPLEMENTATION IN HUMANS

CHAPTER I

INTRODUCTION

Changes from normality of the QT interval in an electrocardiograph (ECG) tracing is regarded as an early indication of possible metabolic and myocardial disturbance. The QT interval represents the time for depolarization and repolarization of the ventricular chambers of the heart to take place. This portion of the cardiac cycle is also referred to as ventricular systole or contraction time. Figure 1 illustrates the position of the QT interval in a sample electrocardiogram.

Purpose of the Study

The purpose of the study was to investigate changes in the QT interval in experienced bicyclists before, during, and after exercise following varied dietary percentages of carbohydrate feedings and vitamin B-6 supplementation.

Significance of the Study

The possibility of a direct relationship between diet and exercise with regard to the QT interval has always existed. Measurement of the QT interval, mathemat-

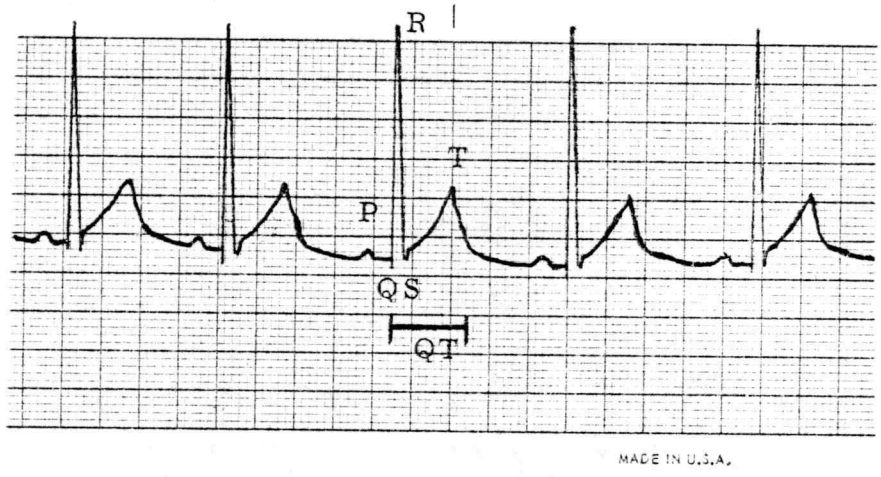

Figure 1. Position of the QT interval in a sample ECG tracing.

ically corrected for heart rate, has made clinical analysis of the QT interval possible. This correction for heart rate of the QT interval is referred to as K, or QT corrected.

When the K value constantly appears beyond normal limits in a resting state, this points to a host of cardiac abnormalities (15,33). These include hypocalcemia, myocardial infarction, and ventricular arrhythmia (15,25,33). A non-significant increase in K during a change from a resting to an exercise state may also indicate such abnormalities in cardiac function (38). The presence of this non-significant increase in K constitutes an abnormal or inadequate response of the heart to meet the increased demand of exercise stress.

Methodology and Delimitations

A comparison of K values were based on six administrations of a 50 minute exercise condition. For control purposes, two exercise conditions were conducted following a normal dietary percentage of carbohydrates during the first week. Two exercise conditions followed periods of low dietary percentages of carbohydrates and high dietary percentages of carbohydrates during the third week. Two exercise conditions were conducted during the sixth week in the same manner as the third week with the

exception of the supplementation of the diets with 8 mg of vitamin B-6.

Data measured reflected heart rate and QT interval responses. The criterion measure was the change in the QT corrected (K) value from a resting to an exercise state at the three work intensities and was represented by D.

Hypotheses

The following three null hypotheses were tested.

1. H_o: No significant difference would exist in D values between exercise sessions following a control diet and two depletion diets at 60%, 80%, and 90% MHR work intensities.

2. H_o: No significant difference would exist in D values between exercise sessions following a control diet and two loading diets at 60%, 80%, and 90% MHR work intensities.

3. H_o: No significant difference would exist in D values between exercise sessions following diets containing 2 mg of vitamin B-6 and diets supplemented with 8 mg of vitamin B-6 at 60%, 80%, and 90% MHR work intensities.

First, the null hypothesis that D values following the depletion diet regimens were equal to the control at the three work intensity levels was tested. Mean values for D at each of the three work intensities

were set equal to: $D_{60\text{-}c1}$, $D_{80\text{-}c1}$, and $D_{90\text{-}c1}$ following the control diet, $D_{60\text{-}d1}$, $D_{80\text{-}d1}$, and $D_{90\text{-}d1}$ following the first depletion diet, and $D_{60\text{-}d2}$, $D_{80\text{-}d2}$, and $D_{90\text{-}d2}$ following the second depletion diet which was supplemented with 8 mg of vitamin B-6. The sub-hypotheses to be tested for each work intensity were:

$$H_o: D_{60\text{-}c1} = D_{60\text{-}d1} = D_{60\text{-}d2}$$

$$H_o: D_{80\text{-}c1} = D_{80\text{-}d1} = D_{80\text{-}d2}$$

$$H_o: D_{90\text{-}c1} = D_{90\text{-}d1} = D_{90\text{-}d2}$$

Second, the null hypothesis that D values following the loading diet regimens were equal to the control at the three work intensity levels was also tested. Mean values for D at each of the three work intensities were set equal to: $D_{60\text{-}c2}$, $D_{80\text{-}c2}$, and $D_{90\text{-}c2}$ following the control diet, $D_{60\text{-}11}$, $D_{80\text{-}11}$, and $D_{90\text{-}11}$ following the first loading diet, and $D_{60\text{-}12}$, $D_{80\text{-}12}$, and $D_{90\text{-}12}$ following the second loading diet which was supplemented with 8 mg of vitamin B-6. The sub-hypotheses to be tested for each work intensity were:

$$H_o: D_{60\text{-}c2} = D_{60\text{-}11} = D_{60\text{-}12}$$

$$H_o: D_{80\text{-}c2} = D_{80\text{-}11} = D_{80\text{-}12}$$

$$H_o: D_{90\text{-}c2} = D_{90\text{-}11} = D_{90\text{-}12}$$

Third, the null hypothesis that D values following diets containing 2 mg of vitamin B-6 were equal to D values following diets supplemented with 8 mg of vitamin B-6 at each of the three work intensity levels was tested. The sub-hypotheses to be tested were:

$$H_o: D_{60\text{-}d1} = D_{60\text{-}d2}$$

$$H_o: D_{80\text{-}d1} = D_{80\text{-}d2}$$

$$H_o: D_{90\text{-}d1} = D_{90\text{-}d2}$$

$$H_o: D_{60\text{-}11} = D_{60\text{-}12}$$

$$H_o: D_{80\text{-}11} = D_{80\text{-}12}$$

$$H_o: D_{90\text{-}11} = D_{90\text{-}12}$$

A two-way analysis of variance was used to determine rejection of the first two null hypotheses (26). Rejection of a sub-hypothesis would indicate that the diet being tested produced unfavorable responses in the QT interval at the exercise work intensity. Not rejecting a sub-hypothesis would indicate that the diet did not produce changes in the QT interval. Pairwise contrasts were used to determine rejection of the third null hypothesis (26). Rejection of a sub-hypothesis would indicate that a vitamin B-6 supplementation of 8 mg produced a more favorable response in the QT interval at the exercise work intensity.

Limitations

The study was limited in the fact that only four subjects comprised the experimental population. Restrictions in funding and logistics made it impractical for a larger sized population to be tested. The findings of this study were based from a tested population of four subjects that were very homogeneous in nature with respect to age and experience. Therefore, caution was and must be exercised when interpreting and applying the results of this study to other populations.

Summary

The availability of ECG equipment, personnel, and a rigidly controlled dietary intake made possible a precise determination of QT interval lengths under the varied conditions of dietary percentages of carbohydrates and vitamin B-6 supplementation. These QT interval measurements gave some indications about possible effects that different types of diet and vitamin B-6 supplementation had on ECG levels, specifically the QT interval, before, during, and after exercise.

Definition of Terms

Aerobic--"Aerobic" referred to work performed at a heart rate less than or equal to 75% of MHR.

Anaerobic--As used in this study "anaerobic" referred to work performed at heart rates exceeding 75% of MHR.

Arrhythmia--"Arrhythmia" described a condition in which an irregularity in the rhythm of the heart beat resulted from an impulse or conduction disturbance.

Bicycle ergometer--"Bicycle ergometer" referred to a stationary bicycle apparatus used for determining the amount of work performed by the rider.

Blood sample #1-3, day #1-6, week #1-6--The preceding terms were used in this study to chronologically list each blood sample, day, and week.

D--"D" as used in this study referred to the numerical difference in seconds between the K value under observation and the K value at rest.

D_{60}, D_{80}, D_{90}--"D_{60}, D_{80}, D_{90}" were used to describe the numerical differences in seconds between the K values at varying work intensities (60%, 80%, and 90% of MHR respectively) and the K value at rest.

Depletion--As used in this study "depletion" referred to a diet consisting of a low percentage of carbohydrate foods.

Electrocardiogram--"Electrocardiogram" described the curve produced by an ECG. This was also referred to as an ECG tracing.

Electrocardiograph--Also referred to as ECG, "electrocardiograph" referred to an instrument used to record electric potentials associated with the electric currents that traverse the heart.

Hypocalcemia--"Hypocalcemia" referred to a condition in the human body in which a low serum calcium level existed.

Loading--"Loading" as used in the present study referred to a diet consisting of a high percentage of carbohydrate foods.

MHR--Also referred to as maximal heart rate, "MHR" described the maximum heart rate an individual was predicted to achieve for his age according to maximum age-specific rate formulas. For this subject population, MHR was equal to 200 beats per minute.

Mixed--Also referred to as normal or control in this study, "mixed" described a diet consisting of a moderate percentage of each of carbohydrate, fat, and protein foods which was typical of the daily intake of an average American adult.

Myocardial infarction--"Myocardial infarction" referred to the death of muscle tissue of the heart resulting from failure of local blood supply to the area.

QT corrected--Also referred to as K, "QT corrected" represented the numerical value derived by dividing the observed QT interval length, measured in seconds, by the square root of the cardiac cycle length, also measured in seconds.

R-R--"R-R" as used in this study referred to the time lapse for the heart to beat once. This was also referred to as a cardiac cycle length.

THR--Also referred to as target heart rate, "THR" described the heart rate which the subjects maintained during a work intensity level. A "THR" in this study was either 60%, 80%, or 90% of MHR.

CHAPTER II

REVIEW OF LITERATURE

The purpose of this study was to investigate changes in the QT interval in experienced bicyclists before, during, and after exercise following varied dietary percentages of carbohydrate feedings and vitamin B-6 supplementation. The significance of such a study seemed to be of major value since no study involving QT interval measurements before, during, and after exercise in combination with dietary intake has been reported in the English Language literature.

The review of literature began with a review of the clinical importance of the QT interval measure as well as the development of its standards, formulas, and range of values. Next, an analysis of the electrocardiographic effects of diet alone was presented. Electrocardiographic effects based on exercise alone was described next. Then, the electrocardiographic effects of diet and exercise in combination with each other was reported. The review concluded with a discussion of the significance of this study based on previous studies reported in the literature in this field.

Clinical Importance of the QT Interval

Electrocardiograms measure electrical potentials associated with waves of excitation which spread through the heart. The science of electrocardiography presents useful information about electrical events of the heart, obtained by recording the voltage produced by the beating heart at the surface of the body (22). The QT interval is an important diagnostic criterion in clinical electrocardiographic analysis (10,15,32,33,35,36). A prolongation of the QT interval beyond normal limits increases the likelihood that a premature beat can occur, thus initiating ventricular fibrillation (32). The significance of a constantly prolonged or shortened QT interval is an early indication of a metabolic disturbance of the muscle tissue of the heart, the myocardium (30). Such departures from normality in the QT interval occur in many conditions including hypocalcemia, myocardial infarction, and ventricular arrhythmia (4,9,10,12,15,25,33,36). The ECG and exercise stress test are crucial tools in the population studies which examine coronary heart disease (7).

History of the Evolution of QT Values

The development of a range of normal values for the QT interval was pioneered by Bazett (5) in 1920. He measured QT interval changes after exercise in a small

number of subjects. His formula produced a constant, K, also termed QT corrected. K was equal to the observed QT interval length measured in seconds, divided by the square root of the cardiac cycle length (R-R), also measured in seconds. Bazett's average values were K=.368 for men, and K=.399 for women. From 1920 to 1962, other studies generally supported Bazett's findings with a range of average K values from .373 to .415 (1-3,17,23,34). These numerous QT measurements of normal, healthy individuals contributed to the formation of a table from which a normal range of limits for specific heart rates was established (1). This table was then the basis for comparing an individual's K value with a normal or average K value. Some values have been suggested that beyond which would indicate an abnormal response. Friedman (15) suggested K=.425 while Isner (18) and Schwartz (33) considered a K greater than .44 to be abnormal.

In 1962, Simonson et al (35) reviewed published formulas and developed a linear equation to predict the QT interval length based on a normal population, given heart rate and age. This formula was expressed as:

$$QT\ normal = .2423 + .140\ (R\text{-}R) + .0003\ (age\ in\ years)$$

Another criterion for QT interval prolongation was developed by Master and Rosenfeld (23) in 1961. Two values were discussed: the QX/QT fraction and the QT

ratio. The former term, the QX/QT fraction, compared the duration of the entire depolarization and repolarization ventricular contraction (QT) in a given heart beat to the duration of ventricular depolarization (QX) in the same beat. The value of using the QX/QT fraction was in assessing S-T segment depression during the heart's contraction. An S-T segment depression of unusually long duration was considered abnormal. The QT ratio on the other hand described the ratio of the QT interval, as measured from an ECG tracing, to a normal QT interval value for the observed heart rate. This normal, or average, QT interval was based on Bazett's K value of .40. Master considered a QX/QT fraction greater than .50 or a QT ratio greater than or equal to 1.08 an abnormal response. A comparison of Bazett's and Master's measurement techniques through mathematical computation showed that a QT ratio equal to 1.08 was equivalent to a K value of .432.

Of the formulas presented, Bazett's formula has been commonly used, particularly in North America. For the purposes of this study, the difference from a resting to an exercise state in the K value produced by Bazett's formula

$$K = \frac{\text{QT interval length (seconds)}}{(\text{R-R})^{\frac{1}{2}} \text{ (seconds)}}$$

was the criterion measure to be examined and tested for significance.

QT interval prolongation as a predictor of sudden death in patients with myocardial infarction was reported by Schwartz and Wolf (33) in 1978. Over a seven year period, 55 patients and 55 controls were ECG monitored in a resting state every two months. The mean K value between patients and controls was significantly different as was the QT variability over several measurements in time. Of the 55 patients who started the study, 27 were still alive at the completion of the seven year study period. A significant difference was found between surviving and deceased patients with respect to the mean K value and its variability. Schwartz and Wolf concluded that a constant prolongation of the QT interval ($K > .44$) would be of help in defining a subgroup of myocardial infarct patients to be at a higher risk for sudden death. The value of such a definition might lead to effective preventive measures for those at a higher risk. The investigators cautioned however, that a prognostic judgement of such an increased risk should be made only on the basis of measurements taken from several ECGs of an individual.

Dietary Influence on the QT Interval

Studies on the effects of diet alone on the QT interval are extremely limited. Isner et al (18) performed a thorough investigation into the effects of the

liquid-protein-modified fast (LPMF) diet on the QT interval in 1979. Prolongation of the QT interval occurred in nine of the ten patients who were dieting and subsequently died. The observed resting QT interval values ranged from .37 to .60 seconds. The corresponding K values ranged from .45 to .65 seconds. The QT intervals were judged to be significantly prolonged both by comparison of K to the arbitrary upper limit of normal of .44 seconds set by Isner (18) and Schwartz (33), and by comparison of the observed QT interval values to the age/rate adjusted normal values presented by Simonson et al (35). In four of the nine patients who had prolonged QT intervals while dieting, pre-dieting ECGs were also available. Of these four ECGs, only one was considered to have an abnormally prolonged QT interval. Hence, the direct effects of the LPMF diet on the prolongation of the QT interval were supported. The unique feature about these nine patients was that most died from ventricular arrhythmias associated with QT interval prolongation after massive, rapid weight loss while on the LPMF diet. Isner felt it was reasonable to believe that QT interval prolongation was the underlying cause of the fatal ventricular arrhythmias in these patients.

Evidence presented by Cahill (11) showed starvation induced certain pathologic alterations of the central nervous system (CNS). This supported Isner's (18)

conclusion that the rapid and extensive weight loss experienced by LPMF dieters induced metabolic alterations affecting the CNS as well as the electrical system of the heart. Further support to this conclusion was lent by Schwartz (32,33) who found that an imbalance in cardiac sympathetic innervation, which prolonged the QT interval, was shown to increase the incidence of arrhythmias associated with coronoary artery occlusion and to lower the ventricular fibrillation threshold.

Studies such as those reported by Isner (18) have raised implications for persons restricting their dietary or carbohydrate intake. The question, "Is a carbohydrate depletion diet possibly harmful to a person's health?", has been seriously addressed in the light of such findings in the literature.

Exercise and the QT Interval

Studies regarding the effects of exercise alone on the QT interval have been more commonly reported than those dealing with diet alone. Exercise testing with ECG monitoring was first proposed by Goldhammer and Scherf (14) in 1932 as an aid in the diagnosis of ischemic heart disease.

The first comprehensive study on the effects of exercise on QT interval lengths before, during, and after

exercise was reported by Yu et al (38) in 1950. Four groups comprised the subject population. These groups were described as normal, hypertensive and arteriosclerotic heart disease, congenital heart disease, and pulmonary heart disease groups. Resting K values were measured from a sitting position rather than the common backlying position. The exercise consisted of a walk on a treadmill for a duration of ten minutes or less, depending on the individual's work tolerance. Only the normal group experienced a significant increase in K during the exercise session compared to their own resting K values. Figure 2a shows the observed pattern of change in the QT interval in this normal group as one of a prolongation of K during exercise, a reduction of K during the first three minutes of recovery, and a return to the resting K value during late recovery. In contrast, Figure 2b shows that none of the three abnormal groups experienced either a significant increase in K values from a resting to an exercise state, or a significant reduction of their average K value during early recovery in comparison with that during resting or exercise states. Failure to meet either of these two criteria constituted an abnormal response of the heart to meet the increased demands of exercise stress. This was an important study in attempting to ascertain patterns contributing to abnormal responses of the heart to exercise stress.

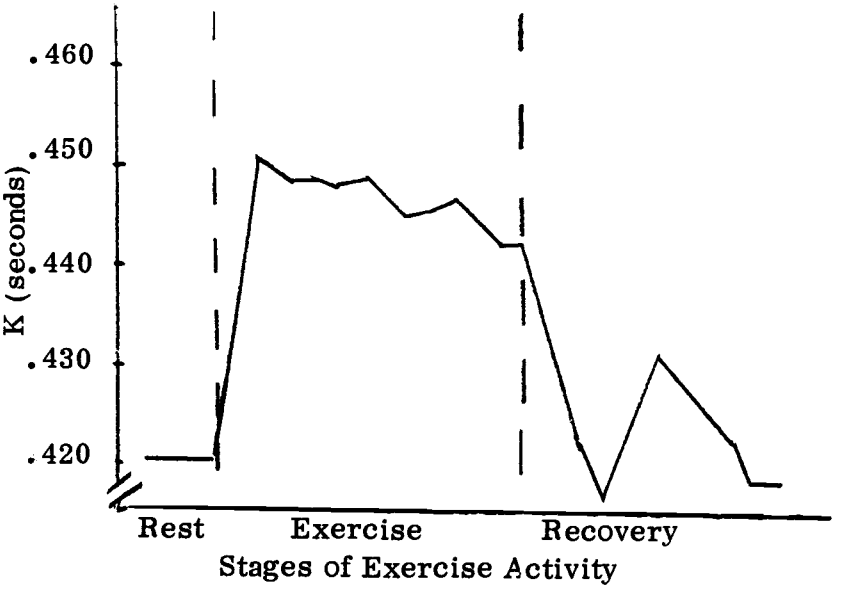

Figure 2a. Normal pattern of change in the QT interval before, during, and after exercise (38).

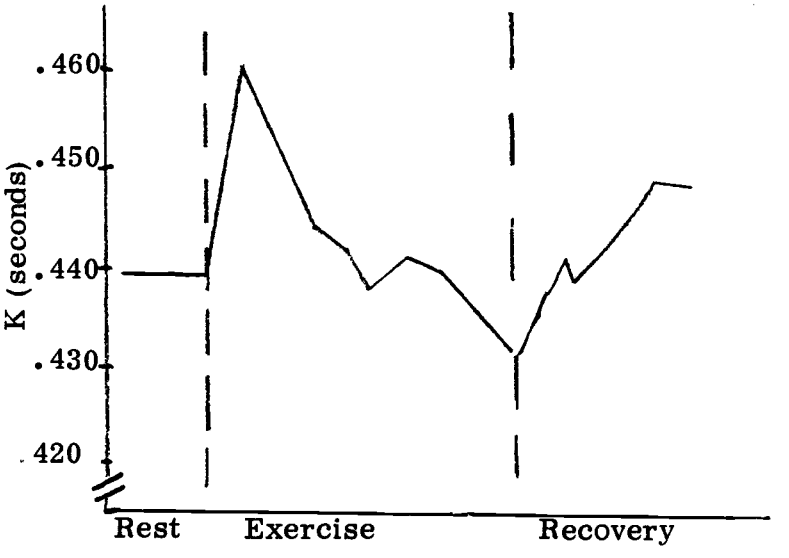

Figure 2b. Abnormal pattern of change in the QT interval before, during, and after exercise (38).

Studies designed to demonstrate what ECG changes would occur in a normal population given a training regime have also been reported. One such study, by LaForge, Wilson, and Obma (19), measured many ECG responses, including the QT interval length, on 36 healthy untrained college males. Responses were measured before and after an eight week training program, but not during the actual exercise activity. These measurements were collected while the subjects were in a resting, supine state. The authors concluded that such a training regime could induce a significant, and therefore favorable, increase in the QT interval due to ventricular volume changes of the heart.

The importance for physicians to recognize ECG changes as normal variants when seen in well-trained athletes also has been emphasized by Lichtman et al (21). The investigators reported that three studies found no significant difference in the QT interval between controls and athletes during exercise. However, in two other studies, the opposite finding was the case. The QT interval was significantly longer in athletes than in the controls during exercise.

Blackburn et al (7) further cautioned that most variations from the normal were nonspecific and there was no agreement among experts about the diagnostic interpretation, cardiac status, or prognosis of these ECG variations.

For this reason, it has been important for the researcher to be very cautious when interpreting ECG responses in light of conflicting findings stated in the literature. A committee of the International Society of Cardiology reported:

> emphasis should be placed on reporting the actual findings without recourse to interpretation which would follow later (29, p. 315).

ECG responses measured both during and after maximal exercise were taken from 20 elite marathon runners as reported by Gibbons et al (16). Although the QT interval was not included in the ECG measurement set, this study was unique in the following regards: 1) the 20 individuals represented one of the most well-trained and highly-conditioned group of athletes ever studied at one time and 2) ECG monitoring was conducted both during and immediately following maximal exercise in contrast to most previous studies' efforts of monitoring only resting (before exercise) ECGs or recovery (after exercise) ECGs. As reported by Blackburn (7) and Lichtman (21), some ECG abnormalities in apparently healthy, young, and well-trained individuals were reasonable due to the training process involved. This training process induced bradycardia (a heart rate of less than 60 beats per minute), an increased R wave voltage, and an increased PR interval.

Gibbons et al (16) found that five of the 20 marathoners showed significant S-T segment depressions after maximal exercise. The fact that these ECG abnormalities found in elite marathoners were the same found in the general population was important. Gibbons cautioned to:

> look beneath apparent ECG abnormalities in otherwise normal, healthy individuals before becoming overly concerned with ECG changes or overly cautions in allowing strenuous activity. The ECG cannot be interpreted in a vacuum (16, p. 283).

Diet and Exercise and their Influence on the QT Interval

The effects on the QT interval before, during, and after exercise in conjunction with a regulated diet was the focus of this study. There has been no study of such a nature reported in the English Language literature to date.

The influence of a carbohydrate diet on exercise was originally studied by Bergstrom et al (6) with respect to work performance. At work intensity levels exceeding 75% of MHR, evidence showed that the larger the initial muscle glycogen stores, the longer work could be performed at a specified work intensity level. Bergstrom found initial glycogen content levels following a three day depletion diet to be only 35% of that measured after a normal diet; initial glycogen stores following a three day

loading diet were twice that found after a normal diet. Similarly, only a performance of limited duration could be achieved following a depletion diet when compared to the normal diet.

During aerobic metabolism, the preference of the heart has been reported to be a ratio of 65% fatty acids and 35% carbohydrates (13). During anaerobic work intensities, the heart further restricts its utilization of carbohydrates and relies predominantly on fatty acids. A build-up of cardiac metabolic waste products and the demands of skeletal muscle for available carbohydrates have been thought to be reasons for the shift of the heart to use a higher percentage of fats as fuel at anaerobic work intensities.

A change in the role of vitamin B-6 metabolism during exercise has been documented in male adolescents (20). Vitamin B-6 is known to be a coenzyme in the metabolism of carbohydrates in the body. The study showed that the demands of exercise changed vitamin B-6 metabolism and led to a redistribution of the vitamin throughout the body. The present study has subsequently suggested that with supplementary amounts of vitamin B-6 in the diet, cardiac metabolism of carbohydrates would increase during aerobic exercise. This would then lead to a more efficient rate of work by the heart.

Three recent studies have attempted to deal with ECG responses, not including the QT interval, to exercise in conjunction with the depletion and loading diets.

Blair et al (8) assembled ten males to follow a seven day diet which consisted of three days of a depletion diet, followed by four days of a loading diet. He measured several ECG responses both before and within 20 minutes following a marathon run completed by all ten subjects. The responses measured were heart rate, PR interval, QRS width, S-T segment deviation, and T-wave height and inversion. The depletion and loading diets had no adverse effects on the ECG responses in this group of marathon runners. It was unfortunate that ECG responses were not measured on the third and final day of the depletion diet. Significant changes and abnormalities may have been occurring in these runners at that time. It was also unfortunate, and perhaps impractical, that ECG responses could not have been measured during exercise.

The influence of glucose, a carbohydrate, in the form of a liquid solution on resting and exercise ECG responses was reported by Riley, Oberman, and Sheffield (30). Thirty-five subjects were tested while running on a treadmill. The findings indicated that the ECG responses were significantly different from normal values in 11 of

the 35 subjects following ingestion of the glucose solution. Riley stated that the variability of response to glucose was dependent in part on the individual's ability to metabolize the solution. This study assessed the effect of glucose intake prior to exercise in contrast to the present study's focus on ECG responses to a diet of three days duration prior to exercise.

A case study of a 40 year old male marathon runner of moderate caliber was outlined by Mirkin (24). While loading in preparation for an upcoming marathon, the runner experienced dull pain in his chest. His ECG showed abnormalities and he did not enter the marathon race. After eating one small meal a day for five consecutive days, pain disappeared, and two weeks later his ECG was judged normal following a daily training run. Mirkin commented that carbohydrate loading and the large, single pre-race meal could raise possible problems for older runners as well as those susceptible to myocardial infarction. Furthermore, he stated that there was a significant relationship between cardiovascular disease and hyperglycemia which could occur during the loading phase. This position was previously stated by Ostrander (27). Unfortunately, this case study was lacking in many specific details. How many days had the runner depleted and loaded? What percentage of carbohydrates was he consuming? At

what point in the six days leading up to the planned marathon run did his pain occur? What kind of training and work intensity was he performing during the depletion and loading phases? Was the abnormal ECG tracing a direct result of depletion and loading diets or were there other hereditary and environmental risk factors involved? Being of moderate athletic caliber, could this athlete's ECG tracing have been misinterpreted?

Summary

The significance of a study which could measure QT interval changes before, during, and after exercise in conjunction with different diets became apparent to this investigator. The review of literature has shown that some aspects of the present study have been reported in various capacities, but the relationship of diet to ECG responses, particularly the QT interval, before, during, and after exercise had not yet been explored. This relationship has been of particular relevance in regard to the increasing interest and involvement with diet, work, recreation, exercise, and competitive athletics. Thus, the application of such a relationship to daily living practices would be a significant and worthy contribution to the literature. It was therefore, the purpose of this study to provide information of such changes in the QT interval and its relationship to diet and exercise.

CHAPTER III

METHODOLOGY

The purpose of this study was to investigate changes in the QT interval in experienced bicyclists before, during, and after exercise following varied dietary percentages of carbohydrate feedings and vitamin B-6 supplementation. Four experienced, college-aged, male bicyclists comprised the subject population. Standard ECG protocol was followed in monitoring the subjects' cardiac responses. Parameters measured were heart rate and the QT interval. The same measurement tools, techniques, and procedures were used during each of the six test administrations for each subject. An experimental research design was constructed to explore causal relationships that dietary and vitamin B-6 conditions would have with the QT interval before, during, and after exercise.

Subjects

Subjects selected were from among a group of experienced bicyclists at Oregon State University. For the purposes of this study, four white males, ranging in age from 20 to 22 years old, who had completed an advanced bicycling class at Oregon State University were selected.

All four subjects were attending college as full-time undergraduates during the experimental period.

Prior to testing, each subject completed a medical history evaluation form and a verification of a physical examination performed by a physician within the past year. The criteria for selection of subjects was predicated upon completion of the preliminary examinations, willingness to be a part of the study, and in maintaining a subject population that was homogeneous in as many factors as possible. This latter criteria was an important process to screen out any extraneous variables which might have influenced the validity of the treatments.

Pre-Testing Procedure

A review was made of each subject's past medical history and physical examination results to determine if any of the selected subjects' histories would contra-indicate their performance in a study of this nature. A formal introductory trial session was then held with the four subjects in which the following material was presented to familiarize them to the testing protocol:

1. Purpose and procedures of the study was described.
2. Subject's role and what was expected of him was also described.
3. Benefits that each subject would receive from participation in the study were presented.

4. All possible risks that were conceivable for a study of this nature were presented.

5. Testing procedures for before, during, and after exercise were demonstrated.

6. Subjects were familiarized with the exercise apparatus--a stationary Monark bicycle ergometer.

7. An informed consent document was administered to and signed by the subjects (see Appendix A).

8. Blackburn CM-5 resting and post-hyperventilation ECGs also were administered to the subjects.

9. Subjects practiced informally on the exercise apparatus.

10. Subjects reconfirmed their willingness to participate in the study.

11. A 20 ml blood sample was collected for blood chemistry screening.

Following the introductory trial session, tracings of each subject's resting and post-hyperventilation ECG was reviewed to determine if any rationale could be found in the tracings which would contra-indicate the subject's performance in the study. The results of any abnormal blood chemistry tests (those outside the normal range) was also reviewed with a physician to determine if this would have contra-indicated the subject's participation in the study.

Blood and urine samples were taken at various intervals during the experimental period by Ann deVos and

Lauren Hatcher of the Foods and Nutrition Department at Oregon State University for the purposes of data collection for their theses. S-T segment responses from ECGs were also obtained by Art Siemann for thesis purposes.

Instrumentation

ECG tracings were obtained from single channel ECG monitoring devices using administrative and operating procedures consistent with the protocol outlined for their use. When a subject was tested he was assigned to the same ECG monitoring device, bicycle ergometer, seat height, testing location, technician, and starting time. The standardization of these extraneous variables prior to the commencement of the study minimized their effect on the validity of the obtained measures. The equipment was calibrated for scientific accuracy prior to the start of the study. Five disposable electrode patches were placed on each subject at the anatomical positions shown in Figure 3.

The lead II and V5 lead tracings were observed at each interval. Procedure consistent with prior studies dictated that the lead where the termination of the T wave was most clearly identified would be the lead from which the QT values would be measured (18). The ECG tracings were taken at a speed of 25 mm/second in all cases.

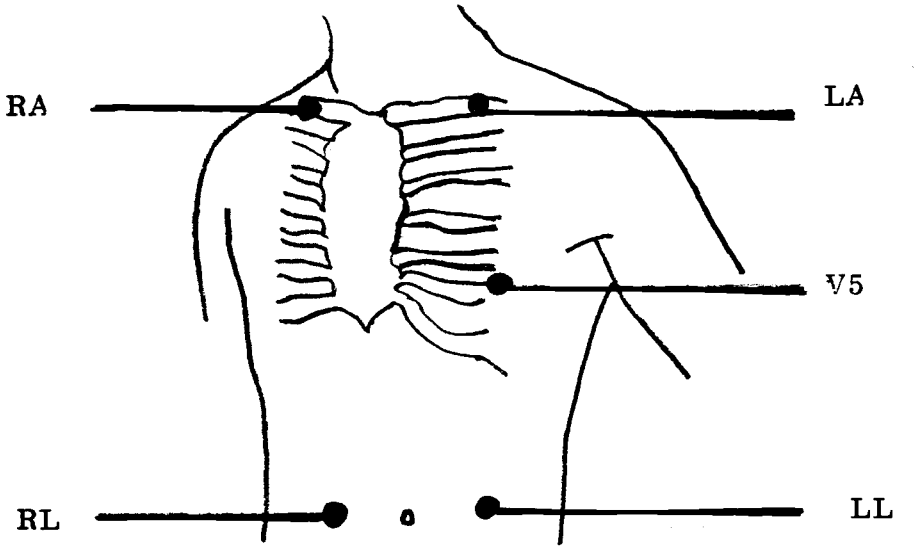

Figure 3. Anatomical positions of electrode patches.

Testing Procedure

The six test administration periods were identified as day #1-6 and were all within six weeks of each other. Days #1, 3, and 5 corresponded to the Wednesdays of weeks #1, 3, and 6, respectively. Similarly, days #2, 4, and 6 corresponded to the Saturdays of weeks #1, 3, and 6, respectively. Subjects were tested at the same time on each of the six days. Individual starting times ranged from 5:45 AM to 7:45 AM (Pacific Standard Time). The diet and exercise schedule of the experimental six week period is presented in Table I. The foods comprising the daily diet contained 2 mg of vitamin B-6. Standardized cooking and feeding procedures were followed for each meal the subjects consumed.

Exercise

The following exercise procedure was adhered to on each of the six testing days.

Before Exercise:

1. A backlying resting ECG tracing was taken in a supine position.
2. A 20 second hyperventilation was performed by the subject in a sitting position.
3. A post-hyperventilation ECG tracing was then taken.

Table I. Diet and exercise schedule during the experimental period.

Week #1	
Diet:	Normal (mixed) diet: 39.9% carbohydrate, 42.5% fat, 17.5% protein; 2 mg vitamin B-6.
Exericse:	Average level of exericse (Sunday-Tuesday), light level of exercise (Wednesday-Friday).
Week #3	
Diet:	Depletion diet: 11.3% carbohydrate, 66.4% fat, 22.3% protein (Sunday-Tuesday); 2 mg vitamin B-6.
Exercise:	Average level of exericse (Sunday-Tuesday), light level of exercise (Wednesday-Friday).
Week #6	
Diet:	Depletion diet: 11.3% carbohydrate, 66.4% fat, 22.3% protein (Sunday-Tuesday); supplement of 8 mg of pyridoxine hydrochloride (vitamin B-6). Loading diet: 70.7% carbohydrate, 12.6% fat, 16.6% protein (Wednesday-Friday); supplement of 8 mg of pyridoxine hydrochloride (vitamin B-6).
Exercise:	Average level of exercise (Sunday-Tuesday), light level of exercise (Wednesday-Friday).

4. Blood sample #1 was drawn before the start of exercise.

During Exercise:

1. Subjects were started on a bicycle ergometer at a rate of 20 km/hr (50 pedal rev/min) with a resistance workload of zero.

2. While maintaining the 20 km/hr rate, the workload was increased until 60% of maximal heart rate (MHR = 200) was achieved (THR = 120).

3. From the initial start point of exercise the workload was then manipulated so as to maintain a 60% MHR for 30 minutes.

4. At the 30 minute mark of exercise the workload was increased to alter the THR to 80% MHR (THR = 160).

5. The 80% MHR level was then maintained for 15 minutes.

6. At the twelfth minute of this 15 minute interval at an 80% MHR level, blood sample #2 was taken.

7. At the 45 minute mark of exercise the workload was increased to alter the THR to 90% MHR (THR = 180).

8. The 90% MHR level was then maintained for five minutes.

9. At the conclusion of the five minute interval at a 90% MHR level, an active recovery phase began. Blood sample #3 was taken at the second minute of this active recovery phase.

10. The active recovery phase was maintained for six minutes.

11. At the conclusion of the six minute active recovery phase, a seated recovery phase of six minutes duration began.

12. ECG tracings and calculations were performed by the technicians at two minute intervals to monitor the subject's performance before, during, and after exercise. In addition, two blood pressure readings were taken: before exercise, and at the fifty-eighth minute. Constant verbal communication was also maintained with the subject.

13. At any time during exercise, the subject or the technician could have terminated the exercise. If any symptoms which contra-indicated the continued performance of exercise occurred, then the exercise was terminated.

After Exercise:

Immediately following the termination of exercise an active recovery period began during which the load was immediately reduced by 50% for the first minute and removed (reduced to zero) for the remaining five minutes. Bicycle ergometer rate was also reduced according to the following sequence.

1. First minute at 20 km/hr.
2. Second and third minutes at 10 km/hr.
3. Fourth, fifth, and sixth minutes at 5 km/hr.

Following the active recovery the subject continued to be monitored during a six minute seated recovery. ECG tracings and blood pressure calculations were taken during the active and seated recovery periods at every minute. Once the subject returned to and maintained a normal

sinus cardiac rhythm, ECG and blood pressure monitoring was discontinued.

Diet

The diets administered to the subjects are shown in Tables II, IIIa, and IIIb. The diets were adequate with all respect to all nutrients for which there were established nutrient requirements. All meals were prepared in the metabolic kitchen of the Foods and Nutrition Department at Oregon State University. On the day of each of the exercise tests, the breakfast meal was served following the exercise session. The subjects exercised following a 12 to 14 hour fast. This fasting period was appropriate for the purposes of this study. Subjects were not allowed to drink water during the exercise or recovery periods. In addition, subjects were not allowed to consume any other food than that which was provided to them. Inappropriate food or water intake would have invalidated the obtained measures. When a supplemental amount (8 mg) of vitamin B-6 was provided during week #6, it was administered in the form of a solution and given with each breakfast meal.

Each subject was expected to fulfill certain requirements during the course of the study. They were:

1. The subjects were to eat all food provided and consume no other food other than water or decaffienated beverages.

Table II. Diet during week #1: normal (mixed) diet. Values following each food represents the food's weight in grams.

Breakfast	Lunch	Dinner
Eggs, 120	Tuna, water-pack, 60	Milk, whole, 250
Toast, wheat, 60	Cheese, cheddar, 60	Hamburger, 180
Orange juice, 250	Salad dressing, 40	Cheese, cheddar, 60
Milk, whole, 250	Bread, wheat, 60	Rice, 60
Margarine, 55	Carrots, 100	Green beans, 100
	Pears, 200	Bread, wheat, 50
	Ginger snaps, 90	
	Candy, 25	

Table IIIa. Diet during the first three days of weeks #3 and 6 (Sunday-Tuesday): depletion diet. Values following each food represents food's weight in grams.

Breakfast	Lunch	Dinner
Eggs, 120	Tuna, oil-pack, 160	Milk, whole, 244
Cheese, cheddar, 73	Bread, wheat 48	Hamburger, 91
Bread, wheat, 74	Celery, 60	Cheese, cheddar, 73
Orange juice, 124	Mayonnaise, 56	Banana, 25
Canadian bacon, 42	Milk, whole, 244	Pineapple, 44
Margarine, 38	Cheese, cheddar 73	Cottage cheese, 123
Cream, 30		

Table IIIb. Diet during the last three days of weeks #3 and 6 (Wednesday-Friday): loading diet. Values following each food represents food's weight in grams.

Breakfast	Lunch	Dinner
Egg, 60	Tuna, water-pack, 80	Milk, skim, 250
Bread, white, 100	Bread, white, 120	Tuna, water-pack, 100
Orange juice, 250	Carrots, 100	Cheese, cheddar, 30
Crispy rice cereal, 70	Salad dressing, 20	Rice, 90
Sugar, white, 15	Raisins, 30	Green beans, 100
Fruit jam, 46	Milk, skim, 250	Bread, wheat, 50
Milk, skim, 500	Ginger snaps, 125	Pears, 200
	Seven-Up drink, 14 oz.	

2. Vitamin or mineral supplements were not to be taken other than those provided.

3. A record of all physical activity during the six week period was to be kept. During the weeks the subjects were fed (weeks, #1, 3, and 6), their exercise activity was monitored by one of the technicians. Each subject was to exercise aerobically for one hour per day on Sunday through Tuesday. This was equivalent to the subjects' normal exercise activity. On Wednesday through Friday, light exercise was prescribed, consisting of 30 minutes of aerobic bicycling.

4. The subjects were to keep a record of the amounts and kinds of all food consumed the week prior to each experimental week, as well as their exercise activity levels.

5. Twenty-four hour urine samples were to be collected each day during the three experimental weeks.

6. The subjects were expected to participate in the exercise procedure as outlined and allow serial blood samples to be collected.

Data Reduction

All QT intervals and R-R cycles were read, measured and recorded by the investigator. All deflections were measured to the nearest one-hundredth of an inch. When converted to an ECG tracing speed of 25 mm/sec, this yielded a corresponding value of one-hundredth of a second. Three successive QT intervals and R-R cycles were measured, and the average value was recorded. A sample

ECG tracing is illustrated in Figure 4 to depict the two measured parameters. Table IV represents sample numerical values of these parameters.

The standard deviation of 23 repeated measures of the same QT interval and R-R cycle, taken over a four week period by the investigator was found to be minimal. Mean and standard deviation values were .28 ± .0000 for the sample QT interval, and 1.6013 ± .0034 for the sample R-R cycle. The mathematical conversion of the repeated measures to K values produced a mean and standard deviation of .3863 ± .0004. These non-significant variations between measurements insured the standardization and reliability of these measurements. The criterion measure for this study was the difference between an observed K value during exercise and the K value at rest. This was represented by D.

Statistical Treatment

An experimental research design was constructed to explore the causal relationships that varied levels of dietary carbohydrate percentages and vitamin B-6 supplementation would have with the QT interval before, during, and after exercise. A two-way analysis of variance was used to determine whether a difference would exist in D values between exercise sessions following a control diet

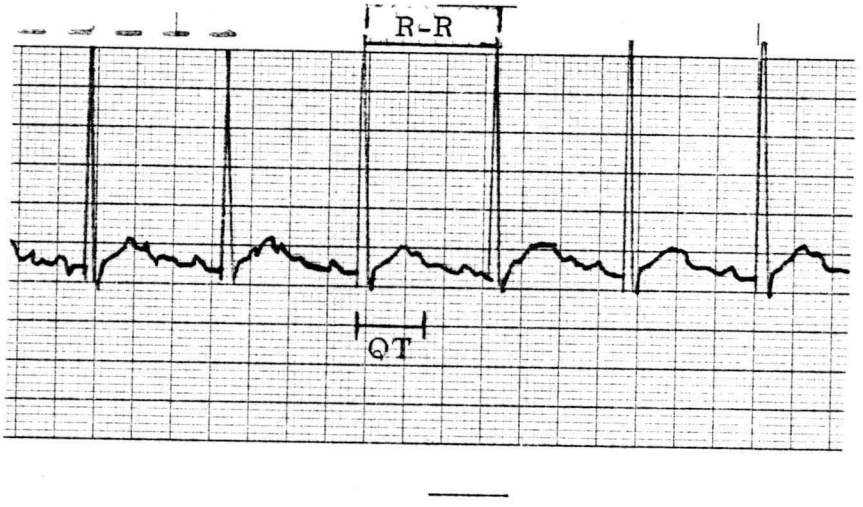

Figure 4. Sample heart rate (R-R) and QT interval measurements from an ECG tracing.

Table IV. Minute of exercise, R-R (inches), QT interval (inches).

Minute	R-R	QT Interval
1	.61	.26
2	.55	.24
3	.57	.29
4	.57	.29
5	.52	.29

and depletion diets at the three work intensities. This statistical treatment was repeated for testing the difference following loading diets. Contrasts of equivalent D values when comparing two levels of vitamin B-6 intake were also used to determine if D values were significantly greater during the period of 8 mg vitamin B-6 supplementation. The significance level for all statistical analyses was .05.

CHAPTER IV

RESULTS AND INTERPRETATION OF DATA

The purpose of this study was to investigate changes in the QT interval in experienced bicyclists before, during, and after exercise following varied dietary percentages of carbohydrate feedings and vitamin B-6 supplementation. An experimental research design was used to explore causal relationships that dietary and vitamin B-6 conditions might have with the QT interval before, during, and after exercise. D values were calculated on the basis of 31 K values collected from the 50 minute exercise period. A two-way analysis of variance and pairwise contrasts were employed to test for the significance of the hypotheses under investigation. Table V presents K values before, during, and after exercise for each of the six exercise days. Figure 5 illustrates the pattern of change in the K values for each of the six exercise days.

Results of Depletion: Hypothesis #1

Table VIa presents data obtained from days #1, 3, and 5, and the analysis of variance of the hypothesis being tested. Figures 6a, 6b, and 6c illustrate the difference between the D values at each of the three work intensities.

Table V. QT values (K in seconds) before, during, and after exercise for the subject population.

	Control Day #1		Control Day #2		Depletion Day #3		Loading Day #4		Depletion, 8 mg vitamin B-6 Day #5		Loading, 8 mg vitamin B-6 Day #6	
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Before Exercise	.366	.024	.352	.019	.376	.022	.357	.038	.363	.016	.356	.032
During Exercise												
60% MHR	.407	.015	.410	.018	.387	.025	.404	.020	.388	.024	.409	.022
80% MHR	.396	.013	.393	.020	.387	.020	.397	.027	.377	.019	.391	.024
90% MHR	.376	.011	.376	.024	.372	.020	.371	.028	.361	.019	.370	.021
After Exercise												
Active Recovery	.380	.029	.374	.012	.358	.018	.369	.013	.361	.015	.377	.022
Seated Recovery	.399	.015	.398	.013	.400	.016	.403	.012	.388	.017	.407	.021

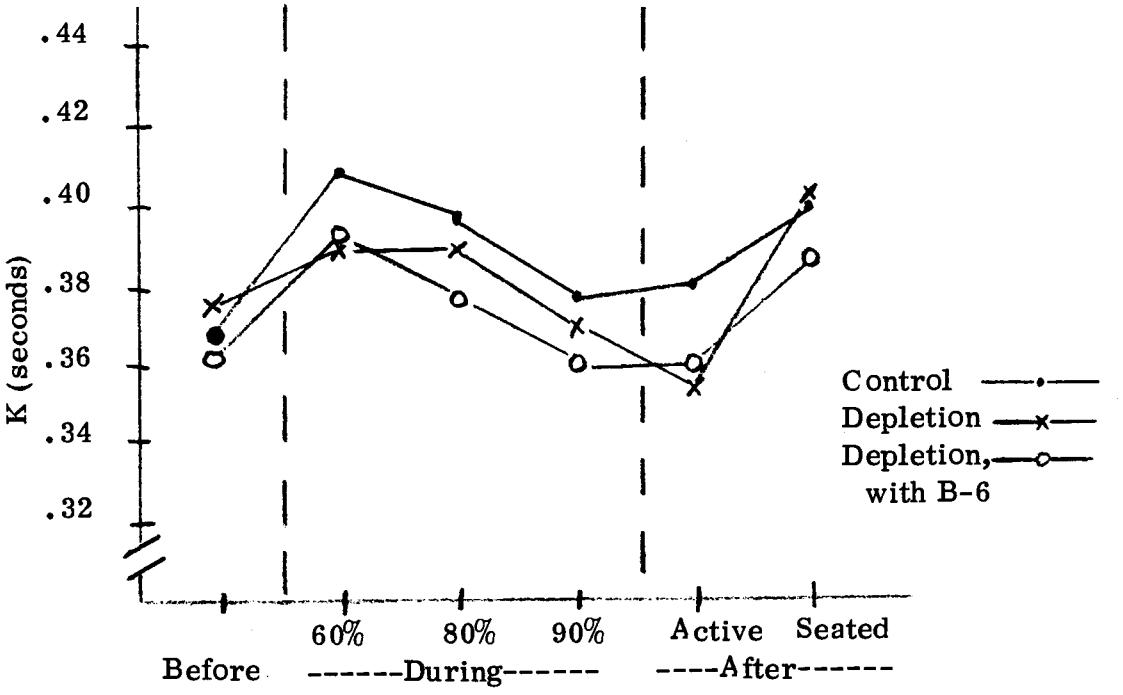

Figure 5a. Changes in mean QT values (K in seconds) before, during, and after exercise following a control diet and two depletion diets.

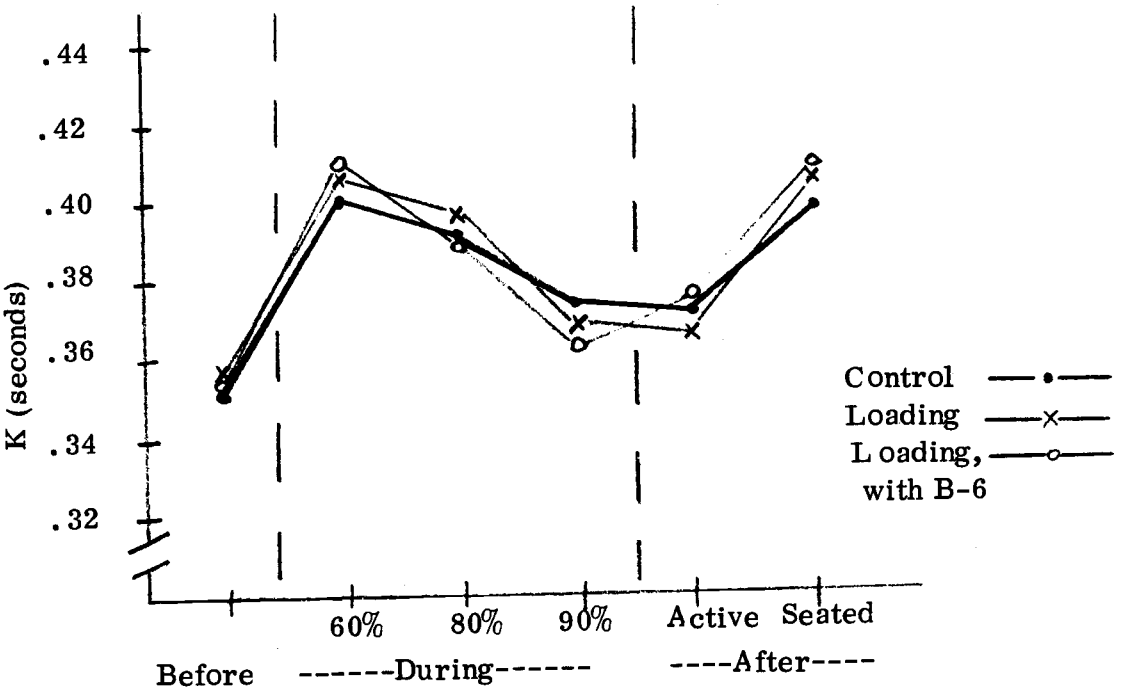

Figure 5b. Changes in mean QT values (K in seconds) before, during, and after exercise following a control diet and two loading diets.

Table VIa. D value (seconds) data following a control diet and two depletion diets, and F ratios for testing H_o: $D_{c1}=D_{d1}=D_{d2}$ at each work intensity.

Work Intensity	Control Day #1 Mean	s.d.	Depletion Day #3 Mean	s.d.	Depletion+B-6 Day #5 Mean	s.d.	F
60% MHR	.041	.015	.011	.025	.025	.024	39.8[a]
80% MHR	.029	.013	.011	.019	.014	.020	12.3[a]
90% MHR	.010	.010	-.004	.019	-.002	.018	4.4[a]

[a]Significant at .05 level. d.f.:2,210(60% MHR);2,90 (80% MHR); 2,54 (90% MHR).

Table VIb. F ratios for pairwise contrasts between D values following a control diet and a depletion diet supplemented with vitamin B-6, at each work intensity.

Work Intensity	F $H_o:D_{c1}=D_{d1}$	F $H_o:D_{c1}=D_{d2}$
60% MHR	79.5[a]	22.5[a]
80% MHR	21.8[a]	14.2[a]
90% MHR	7.4[a]	5.6[a]

[a]Significant at .05 level. d.f.:2,210(60% MHR); 2,90(80% MHR); 2,54 (90% MHR).

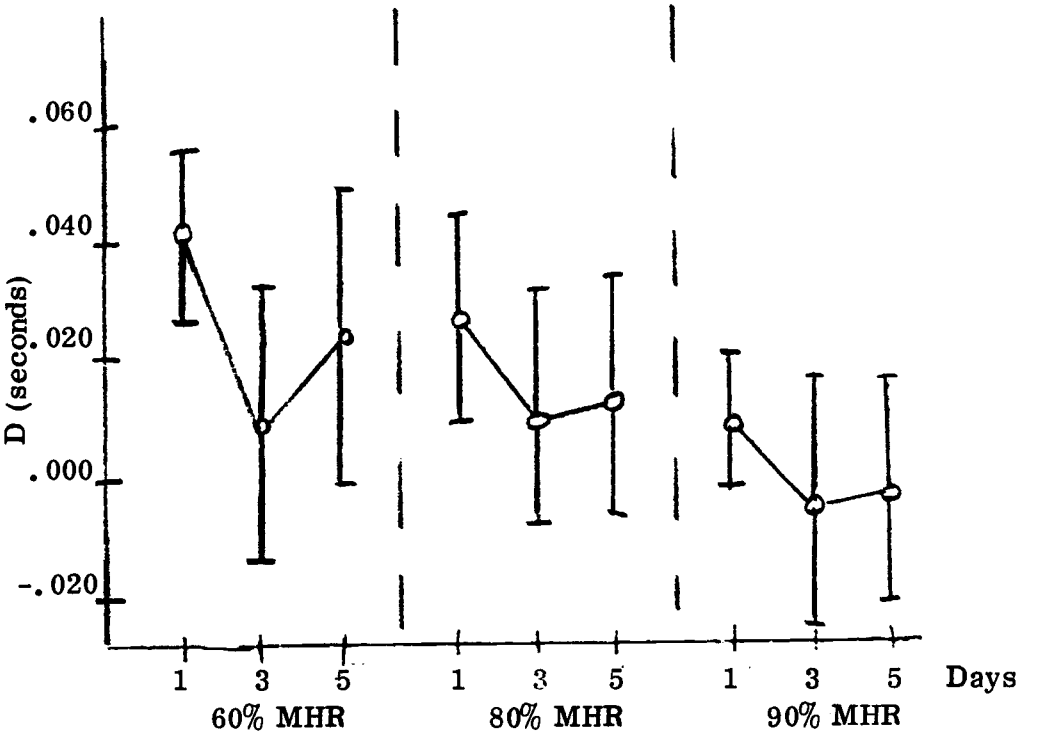

Figure 6a. Means and standard deviations of D following a control diet and two depletion diets at the three work intensity levels.

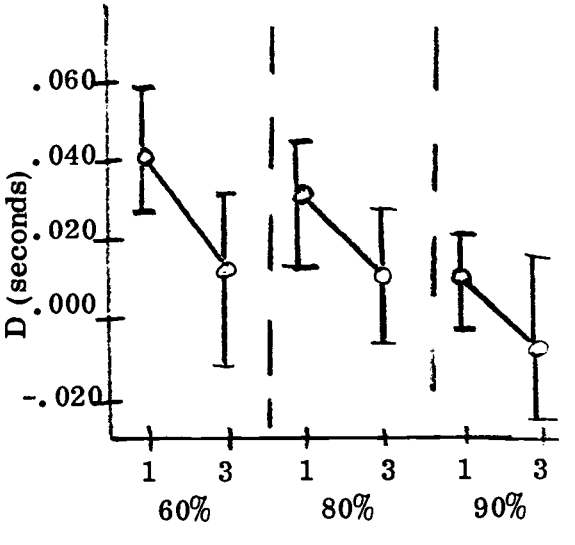

Figure 6b. Means and standard deviations of D following a control diet and a depletion diet.

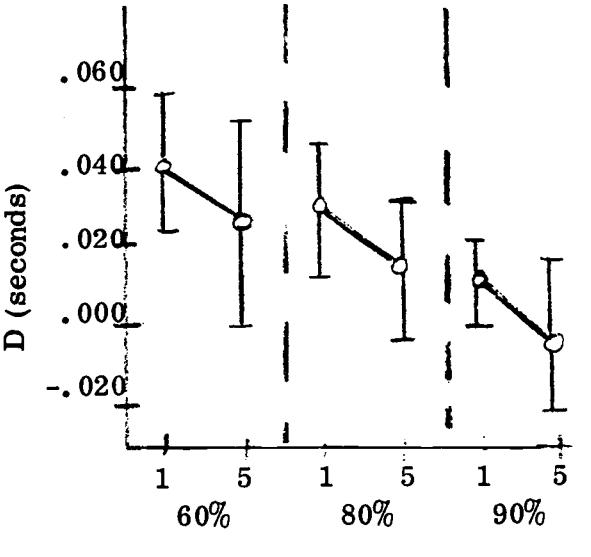

Figure 6c. Means and standard deviations of D following a control diet and a depletion diet supplemented with vitamin B-6.

Interpretation

The null hypothesis stated that D values following the depletion diets were equal to the control at the three work intensities. The alternate hypothesis stated that following the depletion diets, D values would be significantly smaller than the corresponding D values which followed the control diet. The null hypothesis was tested at each of the three work intensities.

Based on values indicated in Table VIa and Figure 6a, the null hypothesis was rejected ($p < .01$) at each of the three work intensities. A difference existed in D values between a normal diet and the two depletion diets. Table VIb and Figures 6b and 6c contrast D values between days #1 and 3, and days #1 and 5. Results indicated that exercise following depletion diets, when compared to the control, produced significantly smaller D values during each work intensity which, in turn, constituted an inadequate response of the heart to meet the demands of exercise stress.

Results of Loading: Hypothesis #2

Table VIIa shows data collected from days #2, 4, and 6, and the analysis of variance of the hypothesis being tested. Table VIIb displays the contrasts and F ratios between the three exercise days under investigation.

Figures 7a, 7b, and 7c depict the difference between the D values for each of the three work intensities.

Interpretation

The null hypothesis stated that D values following the two loading diets were equal to the control at the three work intensities. The alternate hypothesis stated that following the loading diets, D would be significantly smaller than the corresponding D which followed the control diet. The null hypothesis was tested at each of the three work intensities.

Based on values indicated in Table VIIa and Figure 7a, the null hypothesis was not rejected at the 60% MHR and 80% MHR work intensity levels and rejected ($p < .02$) at the 90% MHR work intensity. The only difference that existed in D values between a normal diet and the two loading diets transpired at the 90% MHR work intensity. Table VIIb and Figures 7b and 7c describe the contrasts between days #2 and 4, and days #2 and 6. Results showed that exercise following loading diets when compared to the control produced significantly smaller D values at the final, 90% MHR work intensity level. This represented an inadequate response of the heart to meet the demands of strenuous exercise at a 90% MHR work intensity.

Table VIIa. D value (seconds) data following a control diet and two loading diets, and F ratios for testing $H_o: D_{c2}=D_{11}=D_{12}$ at each work intensity.

Work Intensity	Control Day #2 Mean	s.d.	Loading Day #4 Mean	s.d.	Loading+B-6 Day #6 Mean	s.d.	F
60% MHR	.049	.018	.047	.020	.053	.022	2.8
80% MHR	.041	.020	.040	.027	.035	.024	1.1
90% MHR	.024	.024	.015	.028	.014	.021	3.4[a]

[a]Significant at .05 level. d.f.:2,210(60% NHR); 2,90(80% MHR); 2,54 (90% MHR).

Table VIIb. F ratios for pairwise contrasts between D values vollowing a control diet and a loading diet, and a control diet and a loading diet supplemented with vitamin B-6, at each work intensity.

Work Intensity	F $H_o: D_{c2}=D_{11}$	F $H_o: D_{c2}=D_{12}$
60% MHR	0.90	1.9
80% MHR	0.13	2.0
90% MHR	4.42[a]	5.7[a]

[a]Significant at .05 level. d.f.:2,210(60% MHR; 2,90(80% MHR); 2,54 (90% MHR).

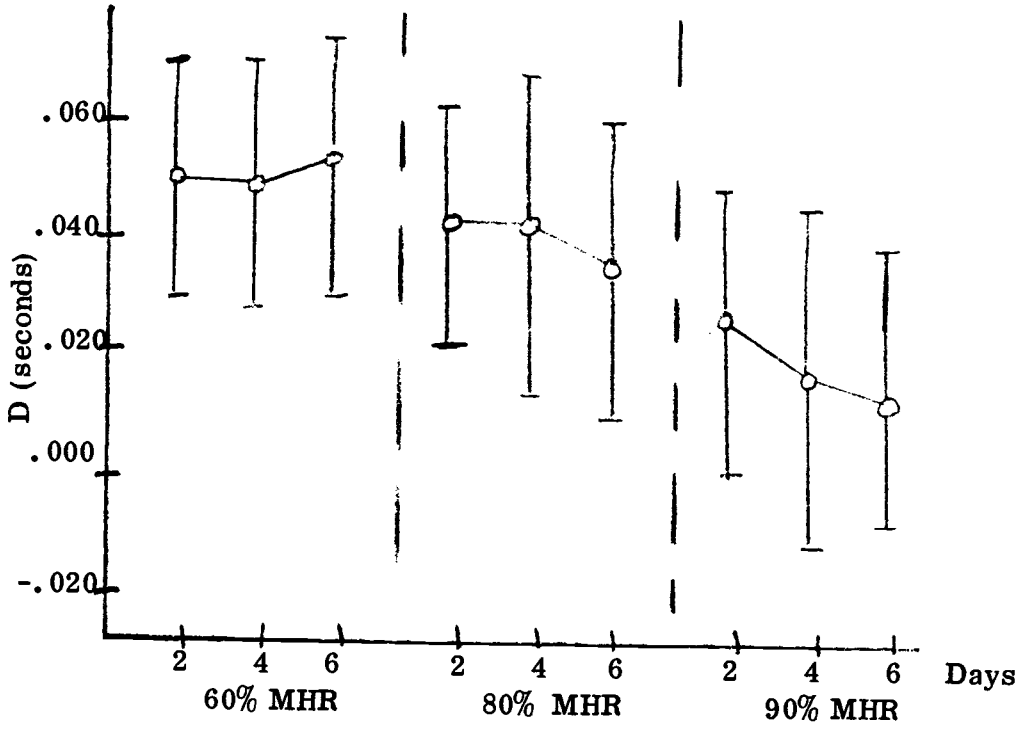

Figure 7a. Means and standard deviations of D following a control diet and two loading diets at the three work intensity levels.

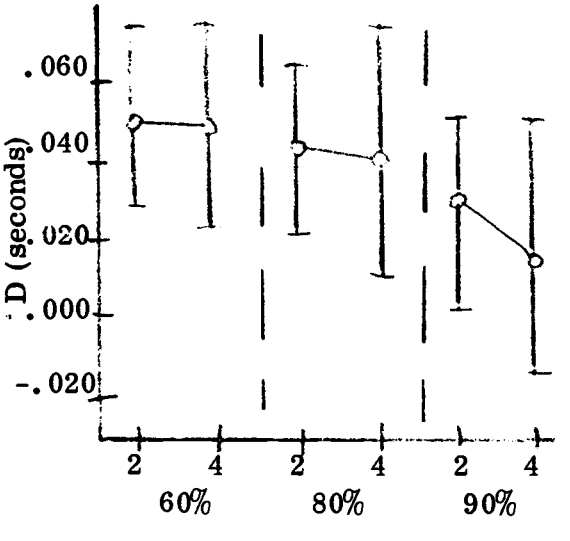

Figure 7b. Means and standard deviations of D following a control diet and a loading diet.

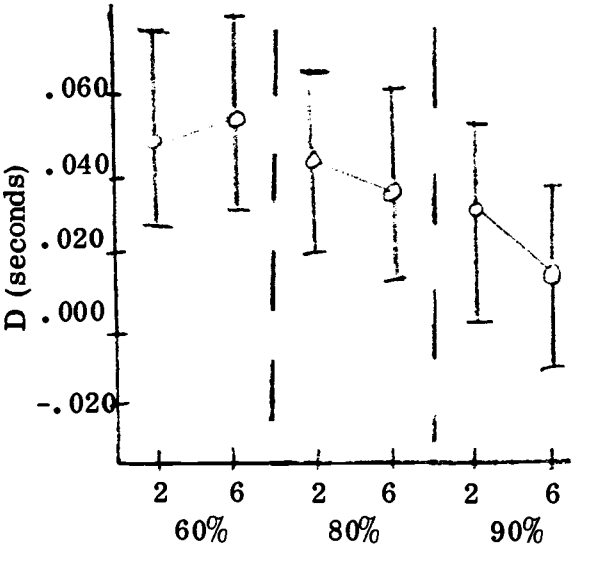

Figure 7c. Means and standard deviations of D following a control diet and a loading diet supplemented with vitamin B-6.

Results of Vitamin B-6: Hypothesis #3

Tables VIa and VIIa have previously presented data obtained from exercise on days #1-6. Table VIII shows the contrasts and F ratios between days #3 and 5, and days #4 and 6 for the purposes of assessing the effects of varied levels of vitamin B-6 intake on the D value. Fugures 8a and 8b describe the difference between the D values for each of the three work intensities.

Interpretation

The null hypothesis stated that D values following vitamin B-6 supplementation would be equal to those values prior to such supplementation to the diet. The alternate hypothesis stated that following vitamin B-6 supplementation, D would be significantly greater than the corresponding D following diets which contained normal amounts (2 mg) of the vitamin. The null hypothesis was tested for each pair of days (depletion days #3 and 5, and loading days #4 and 6) and at each of the three work intensities.

Based on values indicated in Table VIII and Figures 8a and 8b, the null hypothesis was rejected ($p < .01$) at the 60% MHR work intensity level and not rejected at the 80% MHR and 90% MHR work intensities for exercise following both the depletion and loading diets.

Table VIII. F ratios for pairwise contrasts between D values following vitamin B-6 variation at each work intensity.

Work Intensity	F $H_o: D_{d1} = D_{ds}$	F $H_o: D_{11} = D_{12}$
60% MHR	17.39[a]	5.45[a]
80% MHR	0.80	1.09
90% MHR	0.13	0.08

[a]Significant at .05 level. d.f.: 2,210 (60% MHR); 2,90 (80% MHR); 2,54 (90% MHR).

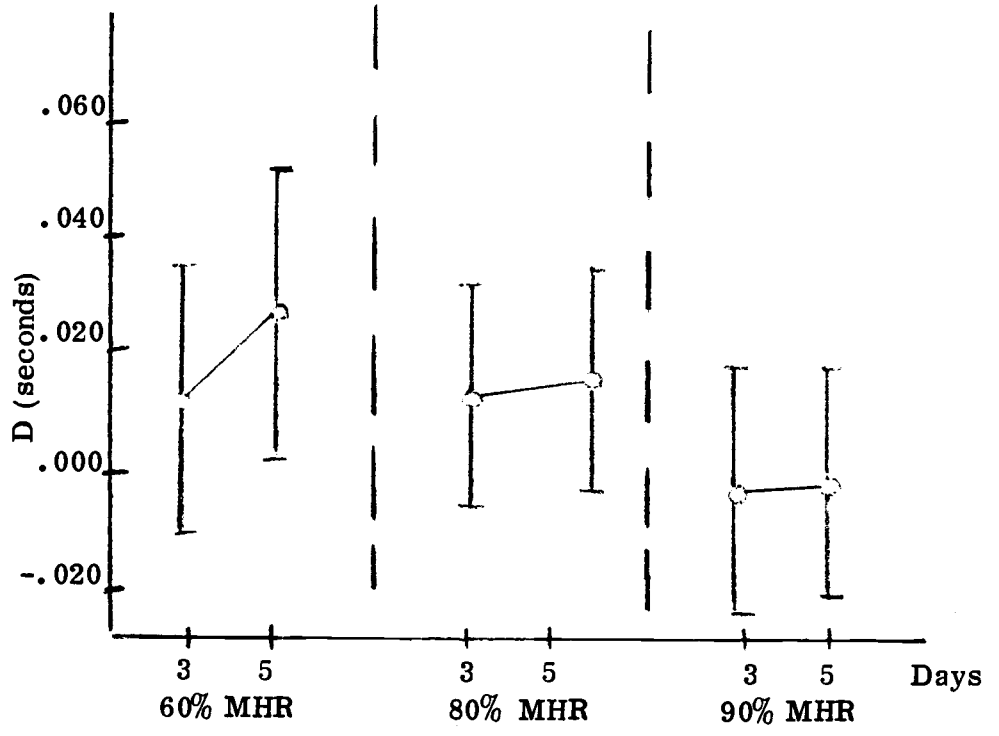

Figure 8a. Means and standard deviations of D following vitamin B-6 variation during two depletion diets at the three work intensity levels.

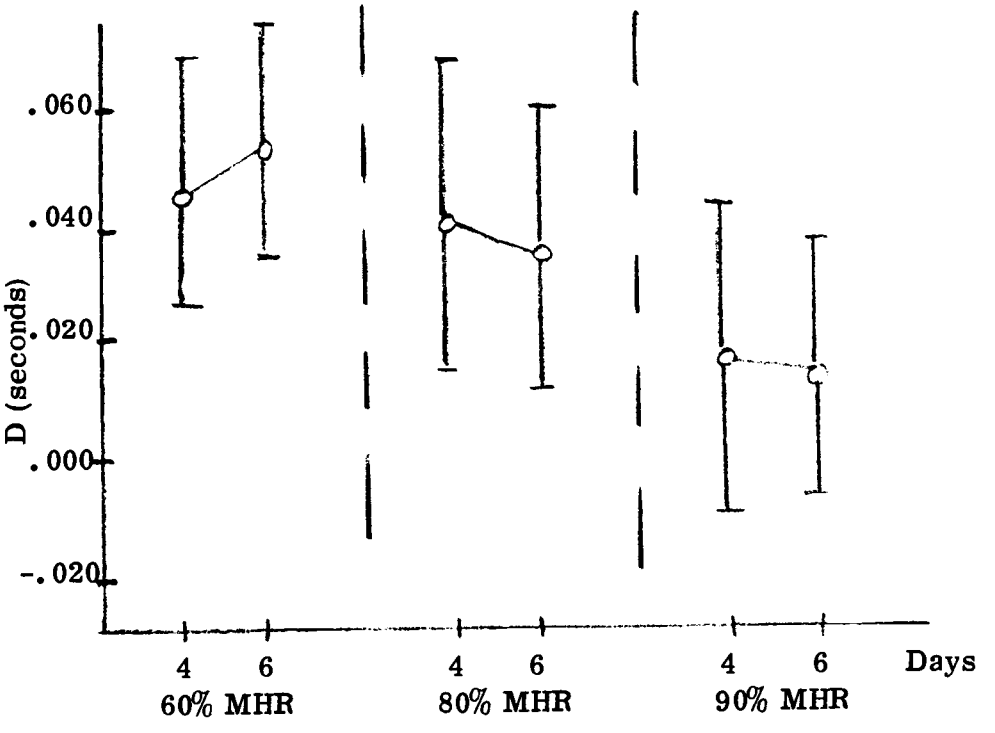

Figure 8b. Means and standard deviations of D following vitamin B-6 variation during two loading diets at the three work intensity levels.

The only difference that existed between D values, when assessing the effects of vitamin B-6, occurred at the 60% MHR work intensity level, regardless of the percentage of carbohydrates in the diet. Interestingly, one subject's D value was significantly ($p < .01$) greater following the depletion diet containing 2 mg of vitamin B-6 than following the same diet supplemented with 8 mg of vitamin B-6.

Discussion

The exploration of the causal relationships that varied levels of dietary carbohydrate percentages and vitamin B-6 supplementation would have with the QT interval before, during, and after exercise proved to be quite revealing. As previously stated, this investigation was unique since no study of this nature was available in the English Language literature. The testing of the three hypotheses disclosed major findings, previously unreported, regarding diet and exercise and their relationship to cardiac function, specifically the QT interval.

First, the study established that the dietary phase consisting of a low percentage of carbohydrates (depletion) was unfavorable for the cardiac demands of exercise stress at all three work intensity levels tested. This finding complements a study reported by Bergstrom et al (6) who analyzed work done by skeletal muscle

following varying percentages of carbohydrates in the diet. The depletion diet was shown to be inadvisable for work performance by the skeletal muscle. The present study has shown that such a diet is also inadvisable for work performance by the cardiac muscle at both aerobic and anaerobic work intensities.

Second, the investigation showed that a diet comprised of a high percentage of carbohydrates (loading) was unfavorable for the cardiac demands of exercise stress at an anaerobic work intensity of 90% MHR. This result suggests that a loading diet is imprudent for work performed by the cardiac muscle at such an extreme work intensity.

Third, the study documented that an increase in the amount of vitamin B-6 in the diet produced a more favorable cardiac response to exercise at an aerobic work intensity of 60% MHR. Vitamin B-6 and its relation to exercise has previously been studied during strenuous exercise (20). That study concluded a redistribution of vitamin B-6 in the body resulted from exercise. An assumption of the present study was that vitamin B-6 would aid in the metabolism of carbohydrates. Since carbohydrates are the body's most readily available source of energy, then cardiac work performance is assumed to be more efficient in response to exercise given the additional vitamin B-6 in the body. The present study established that addi-

tional vitamin B-6 showed a more favorable cardiac response to exercise at an aerobic work intensity of 60% MHR. The fact that this was not significant at anaerobic work intensities may be explained by a greater preference of skeletal muscle for carbohydrates as its major source of fuel during these work intensity levels (13). Thus, the cardiac muscle is influenced to depend more on fats as its predominant source of energy.

A constantly prolonged or shortened QT interval is recognized to be an early indication of a metabolic disturbance of the heart (30). Therefore, the significance of the findings of this study is readily apparent in regard to the increasing interest in diet and exericse. A specific application of depletion and loading diets is followed regularly by athletes prior to a marathon run and other endurance events lasting two hours or more (8,24). The practice of a depletion diet in preparation for such events has serious cardiac implications based on this study's results. The loading diet, however, is safe since the unfavorable anaerobic work intensities of 90% MHR are not normally found in endurance events such as the marathon which typically require work intensities ranging from 70% to 85% of MHR. But work intensities of 90% MHR do occur, particularly in the latter stages of a marathon, when the athlete becomes fatigued. Therefore, caution must be taken by the performer in such instances. Supple-

mentation of vitamin B-6 has been shown to be favorable with respect to cardiac response to exercise at an aerobic work intensity. This is assumed to be due to a cardiac metabolism of a greater amount of carbohydrates. This then facilitates a more efficient work performance by the heart at this work intensity level. For this reason, vitamin B-6 may be of use in aiding the heart to meet the demands of exercise stress which are aerobic in nature. Such a generalization may not always be appropriate, however. The present study showed that one subject's QT interval response to increased vitamin B-6 dosage during a depletion diet was different from the remainder of the group's response. This was true despite an overall group significance in favor of increased vitamin B-6 in the depletion diet. This finding was the only significant variation between subjects in the tested population. A variation such as this must be interpreted cautiously as previously encouraged by several other investigators (16,29).

For this experienced, young, and apparently healthy male subject population, results reported unfavorable cardiac responses for varying work intensities following depletion and loading diets. For each significant result, at least three of the four subjects showed the group pattern of response. It is beyond the scope of appropriateness of this investigator to make clinical

judgements concerning medical abnormalities that are likely to be reflected in the ECG tracings following such dietary departures from normality. Suffice it to state, however, common abnormalities that could develop are ventricular arrhythmias or myocardial infarctions (15,25,33). Upon extrapolating these unfavorable effects on the heart to a population which has more coronary risk factors with respect to age, training state, and heredity, then it is clear the depletion and loading diets are inadvisable whether they are to be tools used for the purposes of a reducing diet or an upcoming endurance event such as the marathon run.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

No study has been reported in the English Language literature which has assessed the relationship of the QT interval to both diet and exercise in regard to before, during, and after exercise activity. The purpose of this study was to investigate this relationship. Specifically, the purpose was to investigate changes in the QT interval in experienced bicyclists before, during, and after exercise following varied dietary percentages of carbohydrate feedings and vitamin B-6 supplementation.

Procedures

Four experienced, college-aged, male bicyclists comprised the subject population. Heart rate and QT intervals were monitored by ECG monitoring devices at continuous intervals before, during, and after exercise. Each time a subject was tested he was assigned to the same ECG monitoring device, bicycle ergometer, seat height, testing location, technician, and starting time. Furthermore, inappropriate drink and food intake was disallowed since it could have invalidated the obtained measures.

Data Analysis

Data were grouped according to the types of diets administered. A two-way analysis of variance for depletion diets and loading diets was performed on D values obtained from the three work intensity levels. Pairwise contrasts were performed to test for the effects of vitamin B-6 on D values. The .05 level of significance was chosen for rejection of the null hypothesis in this study.

Conclusions

An analysis of the data led to the following conclusions:

1. D values differed significantly for all three work intensities when depletion diets were compared to a control diet.
2. D values differed significantly at the 90% MHR work intensity when loading diets were compared to a control diet.
3. D value increases differed significantly at the 60% MHR work intensity when diets supplemented with 8 mg of vitamin B-6 were compared to those diets containing 2 mg of vitamin B-6.

Recommendations

This study demonstrated that for the subject population under examination: a depletion diet resulted

in an unfavorable QT interval response at all three work intensities, a loading diet resulted in an unfavorable QT interval response at the 90% MHR work intensity, and vitamin B-6 supplementation resulted in a more favorable QT interval response at the 60% MHR work intensity.

For Further Study

1. The subject population should be increased to include individuals of both sexes and of different age levels. An increase in sample size within each strata would further support statistical conclusions.

2. A study in which performers of short work duration ("sprint-trained") are compared to those of long work duration ("endurance-trained") would be of particular use in examining the effects of vitamin B-6 would have on the two distinct populations' criterion measures.

3. An increase in exercise duration of up to 180 minutes might be of greater value in applying findings to longer endurance events such as the marathon run.

For Practice

1. The depletion diet should be considered inadvisable whether it is to be used for the purposes of a reducing diet or an upcoming endurance event.

2. The loading diet should be used with caution when considering exercise requiring a work intensity of 90% of MHR.

3. Vitamin B-6 supplementation would aid in carbohydrate metabolism and cardiac response when considering exercise requiring a work intensity of 60% of MHR. Such a practice would be inadvisable, however, for events of one hour or more in duration which require a strict savings of carbohydrates as fuel.

REFERENCES

1. American Heart Association. The ECG Test Book. New York: American Heart Association Communications Division, 1956.

2. Ashman, R., and Hull, E. Essentials of Electrocardiography. New York: The MacMillan Co., 1945.

3. _____. "Normal Duration of Q-T Interval." Proceedings of the Society for Experimental Biology and Medicine 40 (February 1939):150.

4. Barker, S., Johnston, F.D., and Wilson, F.N. "The Duration of Systole in Hypocalcemia." American Heart Journal 14 (July 1937):82-86.

5. Bazett, H.C. "An Analysis of the Time Relations of Electrocardiograms." Heart 7 (1920):353-370.

6. Bergstrom, J., Hermansen, L., Hyltman, E., and Saltin, B. "Diet, Muscle Glycogen, and Physical Performance." Acta Physiological Scandinavica 71 (October 1967):140-150.

7. Blackburn, H. et al. "The ECT in Population Studies." Circulation 21 (June 1960):1160-1175.

8. Blair, S. et al. "Blood Lipid and ECG Responses to Carbohydrate Loading." The Physician and Sportsmedicine 8 (July 1980):69-75.

9. Bronsky, D. et al. "Calcium and the ECG." American Journal of Cardiology 7 (June 1961):840-843.

10. Burch, G.E., and Winsor, T. A Primer of Electrocardiography. Philadelphia: Lea and Febiger, 1972.

11. Cahill, G.F. "Starvation in Man." New England Journal of Medicine 282 (March 19, 1970):668-675.

12. Dreifus, L.S., and Pick, A. "A Clinical Correlative Study of the Electrocardiogram in Electrolyte Imbalance." Circulation 14 (November 1956):815-825.

13. Ellestad, M.H. Stress Testing Principles and Practices. Philadelphia: F.A. Davis Co., 1980.

14. Faris, J.V., McHenry, P.J., and Morris, S.N. "Concepts and Applications of Treadmill Exercise Testing and the Exercise Electrocardiogram." American Heart Journal 95 (January 1978):102-114.

15. Friedman, H.H. Diagnostic Electrocardiography and Vectorcardiography. New York: McGraw-Hill, 1971.

16. Gibbons, L.W., Cooper, K.H., Martin, R.P., and Pollock, M.L. "Medical Examination and Electrocardiographic Analysis of Elite Distance Runners," in Annals of the New York Academy of Sciences 301:(1977), pp. 283-296. Edited by Paul Milvy.

17. Hegglin, R., and Holzmann, M. "Die Klinische Bedeutung der Verlangerten QT-Distanz (Systolendauer) im Electrokardiogram." Ztscher F Klin Med 132 (1937):1-32.

18. Isner, J.M. et al. "Sudden, Unexpected Deat in Avid Dieters Using the Liquid-Protein-Modified Fast Diet." Circulation 60 (December 1979):1401-1412.

19. LaForge, R., Wilson, P., and Obma, R. "Cardiac Effects of Running in Untrained College Men." The Physician and Sportsmedicine 5 (July 1977):72-79.

20. Leklem, J.E., Schultz, T.D., and Miller, L.T. "Vitamin B-6 Metabolism in Male Adolescents." Federation Proceedings 38 (April 1979):452 (Abstract).

21. Lichtman, J. et al. "ECG of the Athlete." Archives of Internal Medicine 132 (November 1973):763-770.

22. Little, Robert C. Physiology of the Heart and Circulation. Chicago: Year Book Medical Publishers, 1977.

23. Master, A.M., and Rosenfeld, I. "Criteria for the Clinical Application of the Two-Step Exercise Test." Journal of the American Medical Association 178 (October 21, 1961):283-289.

24. Mirkin, G. "Carbohydrate Loading: A Dangerous Practice," Letter to the Editor. Journal of the American Medical Association 223 (March 26, 1973):1511-1512.

25. Moss, A.J., and Schwartz, P.J. "Sudden Death and the Idiopathic Long Q-T Syndrome." American Journal of Medicine 66 (January 1979):6-7.

26. Neter, J., and Wasserman, W. Applied Linear Statistical Models. Homewood, Illinois: Richard D. Irwin, Inc., 1974.

27. Ostrander, L.D. et al. "The Relationship of Cardiovascular Disease to Hyperglycemia." Annals of Internal Medicine 62 (June 1965):1188-1198.

28. Rashoff, W.J. "The Athletic Heart." Journal of the American Medical Association 236 (July 12, 1976):158-162.

29. Research and Social Committees of the International Society of Cardiology: Joint Report. Session in Brussels, Belgium, September 15 and 19, 1958. Circulation 19 (February 1959):314-317.

30. Riley, C.P., Oberman, A., and Sheffield, L.T. "Electrocardiographic Effects of Glucose Ingestion." Archives of Internal Medicine 130 (November 1972): 703-707.

31. Rushmer, R.F. Structure and Function of the Cardiovascular System. Philadelphia: W.B. Saunders Co., 1976.

32. Schwartz, P.J., Poriti, M., and Malliami, A. "The Long QT Syndrome." American Heart Journal 89 (March 1975): 378-390.

33. _____, and Wolf, S. "QT Interval Prolongation as a Predictor of Sudden Death in Patients with Myocardial Infarction." Circulation 57 (June 1978):1074-1077.

34. Shipley, R.A., and Halloran, W.R. "Four-Lead ECG in 200 Normal Men and Women." American Heart Journal 11 (March 1936):325-245.

35. Simonson, E. et al. "The Normal QT Interval." American Heart Journal 63 (June 1962):747-753.

36. Surawicz, B. "Electrolytes and the Electrocardiogram." American Journal of Cardiology 12 (November 1963):656-662.

37 _____. "Pitfalls in Interpretation of Electrocardiographic Stress Tests." Postgraduate Medicine 65 (February 1979):54-69.

38. Yu, P.N.G., Bruce, R.A., Lovejoy, F.W., and Pearson, R. "Observations of the Change of Ventricular Systole (QT Interval) During Exercise." Journal of Clinical Investigation 29 (March 1950):279-289.

39. Zohrman, L.R., and Phillips, R.E. Medical Aspects of Exercise Testing and Training. New York: Intercontinental Medical Book Corp., 1973.

APPENDICES

Appendix A

Informed Consent Form

I, _____*_____, give my consent to participate in this study. The study has been explained to me and all my questions have been answered. I agreed to consume all food and vitamin supplements provided and to provide a record of food consumed the week prior to each experimental week. I agree to participate in the bicycle ergometer test which will be conducted on Wednesday and Saturday of each experimental week. I understand that there is a risk of a heart attack during a test such as this and that the type of exercise procedure to be conducted has been explained and the equipment used to in these procedures monitor heart (cardiac) function has been demonstrated. I further agree to participate only after a clearance of a physician is given. I agree to allow 20 ml blood samples to be collected at five times during each exercise test and to collect 24 hour urine samples through each of the three experimental periods.

I understand that I will be paid $50.00 upon completion of the study. I understand that I am free to withdraw from the study at any time and that I can terminate the exercise part of the study at any time. I also understand that the investigators reserve the right to withdraw me from this study at any time.

All information concerning me will be kept confidential.

Name _____ Date _____

Witness _____ Date _____

*Subject's name deleted to protect his rights to anonymity.

APPENDIX B

Heart Rate (HR) and QT Interval (inches) Data

Day #1 (Control)	Subject #1		Subject #2		Subject #3		Subject #3	
Minute of Exercise	HR	QT	HR	QT	HR	QT	HR	QT
0	50	.38	56	.35	47	.44	55	.38
1	107	.31	93	.31	-	-	107	.31
2	104	.29	86	.32	-	-	110	.31
3	-	-	111	.28	89	.35	108	.30
4	107	.30	127	.28	-	-	120	.29
5	130	.28	127	.25	107	.31	121	.29
6	138	.27	140	.26	116	.30	123	.29
8	127	.26	132	.24	110	.31	115	.28
10	137	.26	124	.27	127	.30	120	.29
12	128	.26	128	.28	123	.28	123	.28
14	119	.27	121	.27	126	.29	129	.27
16	117	.28	114	.27	121	.29	125	.28
18	117	.28	116	.27	120	.29	120	.29
20	116	.28	124	.27	121	.29	128	.29
22	115	.28	125	.26	121	.28	109	.31
24	116	.27	122	.27	126	.29	116	.30
26	117	.28	121	.26	126	.29	109	.31
28	120	.28	121	.26	119	.30	130	.29
30	122	.28	126	.25	119	.30	127	.29
32	145	.25	136	.25	138	.28	136	.28
34	145	.25	144	.23	149	.27	144	.26
36	150	.24	150	.23	155	.26	155	.24
38	154	.23	161	.23	164	.25	163	.25
40	154	.24	166	.22	164	.25	153	.25
42	154	.24	167	.21	157	.26	157	.24
44	154	.23	167	.21	158	.24	154	.24
45	153	.23	166	.22	157	.26	164	.23
46	154	.22	169	.21	164	.25	167	.22
47	163	.22	177	.20	169	.24	172	.22
48	169	.23	183	.20	175	.23	174	.21
49	172	.21	188	.19	177	.24	179	.22
50	181	.20	188	.19	181	.23	179	.22
51	169	.22	177	.21	169	.25	166	.22
52	135	.24	154	.22	138	.27	135	.24
53	117	.24	140	.23	127	.29	120	.27
54	115	.27	131	.23	118	.29	121	.28
55	112	.28	132	.23	109	.30	121	.29
56	110	.29	-	-	108	.30	109	.29
57	104	.28	-	-	92	.33	111	.30
58	100	.29	129	.26	99	.22	102	.30
60	102	.30	119	.27	89	.33	102	.30
62	93	.31	118	.27	93	.33	104	.30

Day #2 (Control)	Subject #1		Subject #2		Subject #3		Subject #4	
Minute of Exercise	HR	QT	HR	QT	HR	QT	HR	QT
0	41	.40	53	.35	44	.42	55	.38
1	88	.31	81	.31	69	.36	89	.34
2	93	.31	96	.30	89	.34	109	.31
3	91	.31	106	.29	94	.32	112	.30
4	102	.30	117	.29	100	.32	-	-
5	104	.30	122	.29	102	.30	-	-
6	116	.30	122	.28	101	.30	100	.31
8	115	.30	122	.28	114	.29	109	.29
10	122	.29	120	.28	114	.29	109	.29
12	120	.28	121	.26	117	.28	130	.28
14	121	.28	124	.25	118	.30	111	.29
16	121	.28	122	.27	119	.28	124	.27
18	120	.28	119	.28	118	.29	136	.25
20	123	.29	121	.27	118	.29	124	.27
22	117	.28	122	.27	121	.27	121	.27
24	121	.27	116	.28	123	.29	128	.27
26	114	.28	121	.28	125	.28	129	.27
28	115	.28	126	.27	130	.27	131	.26
30	116	.28	111	.27	127	.28	127	.28
32	141	.26	137	.26	134	.27	146	.25
34	150	.25	-	-	144	.27	146	.25
36	160	.24	141	.25	148	.27	148	.25
38	160	.23	151	.24	157	.25	157	.23
40	164	.22	155	.24	157	.25	157	.23
42	161	.22	160	.24	157	.24	163	.22
44	164	.23	157	.24	161	.24	155	.23
45	164	.22	150	.25	161	.24	157	.23
46	169	.24	161	.23	164	.23	163	.22
47	172	.23	174	.22	169	.23	167	.22
48	172	.22	175	.22	172	.22	169	.22
49	174	.22	183	.21	174	.21	170	.21
50	174	.22	186	.20	179	.20	174	.21
51	161	.23	177	.21	169	.23	153	.24
52	128	.24	154	.22	138	.24	131	.25
53	118	.27	131	.24	127	.25	119	.27
54	111	.28	127	.25	113	.26	116	.27
55	116	.29	123	.26	113	.27	111	.29
56	105	.30	121	.27	106	.30	108	.30
57	109	.29	114	.28	96	.31	103	.30
58	121	.28	106	.28	97	.31	98	.31
60	107	.30	103	.28	89	.33	97	.31
62	100	.30	103	.29	91	.33	102	.31

Day #3 (Depletion) Minute of Exercise	Subject #1		Subject #2		Subject #3		Subject #4	
	HR	QT	HR	QT	HR	QT	HR	QT
0	43	.41	56	.37	55	.45	56	.40
1	81	.27	99	.29	86	.35	89	.32
2	100	.22	110	.29	91	.35	102	.30
3	109	.22	116	.28	98	.33	107	.30
4	111	.23	107	.27	96	.32	111	.29
5	109	.23	126	.26	102	.31	109	.29
6	121	.23	129	.25	105	.30	127	.28
8	118	.22	114	.25	110	.30	122	.29
10	125	.22	121	.26	117	.29	122	.29
12	121	.22	123	.25	118	.28	118	.28
14	121	.22	121	.25	113	.29	118	.29
16	117	.28	117	.25	118	.28	118	.28
18	121	.27	121	.25	115	.29	121	.28
20	120	.29	126	.25	117	.29	121	.28
22	120	.28	125	.26	122	.30	116	.28
24	121	.28	121	.26	118	.30	119	.28
26	118	.28	118	.27	114	.30	118	.29
28	118	.28	111	.27	118	.30	119	.29
30	116	.26	120	.27	114	.30	114	.29
32	127	.26	136	.25	128	.28	131	.28
34	138	.25	140	.25	143	.26	148	.25
36	151	.25	155	.22	153	.25	148	.25
38	157	.24	158	.22	155	.24	151	.24
40	157	.25	153	.22	160	.24	160	.24
42	161	.22	157	.22	161	.24	157	.23
44	158	.23	158	.22	158	.24	163	.22
45	158	.22	160	.22	157	.25	157	.22
46	164	.23	167	.21	164	.23	166	.23
47	167	.22	172	.21	166	.23	172	.21
48	172	.23	175	.20	169	.23	175	.21
49	174	.22	177	.20	174	.22	177	.21
50	181	.20	179	.20	177	.22	181	.21
51	167	.20	169	.20	163	.23	169	.21
52	136	.23	149	.21	136	.25	137	.23
53	115	.26	127	.23	112	.26	116	.27
54	117	.27	126	.25	108	.27	122	.27
55	117	.28	124	.26	104	.30	112	.28
56	112	.30	128	.26	102	.30	109	.29
57	101	.29	111	.27	101	.30	101	.30
58	102	.29	109	.28	88	.33	101	.30
60	101	.30	110	.28	90	.33	99	.32
62	107	.30	106	.28	89	.35	97	.31

Day #4 (Loading)	Subject #1		Subject #2		Subject #3		Subject #4	
Minute of Exercise	HR	QT	HR	QT	HR	QT	HR	QT
0	37	.40	49	.36	40	.46	60	.39
1	81	.34	92	.31	78	.36	102	.35
2	76	.34	102	.30	78	.35	113	.35
3	90	.32	113	.27	93	.33	114	.31
4	86	.31	109	.26	98	.31	116	.31
5	94	.31	119	.26	104	.31	112	.31
6	104	.30	121	.27	108	.30	121	.32
8	107	.29	120	.27	124	.29	121	.30
10	107	.29	117	.26	114	.29	120	.30
12	114	.29	119	.26	114	.29	120	.30
14	117	.29	118	.26	118	.28	111	.31
16	116	.29	117	.26	118	.29	127	.31
18	118	.27	117	.26	118	.29	125	.31
20	118	.29	117	.26	118	.29	120	.31
22	117	.26	122	.26	117	.29	118	.30
24	116	.27	121	.26	127	.29	113	.30
26	124	.27	116	.26	116	.28	118	.30
28	117	.26	114	.26	118	.28	121	.29
30	115	.26	118	.26	124	.29	114	.31
32	137	.26	131	.26	126	.28	128	.29
34	143	.26	146	.25	136	.27	134	.28
36	148	.24	153	.25	144	.27	149	.26
38	157	.24	158	.23	149	.27	150	.25
40	155	.24	160	.23	150	.26	155	.24
42	157	.23	164	.22	151	.26	158	.23
44	163	.22	166	.22	160	.25	160	.24
45	164	.21	163	.23	161	.24	161	.23
46	169	.21	172	.23	164	.24	161	.23
47	174	.20	177	.22	166	.23	167	.23
48	174	.21	179	.20	169	.22	172	.23
49	177	.21	177	.20	169	.22	175	.21
50	177	.20	181	.20	169	.21	175	.21
51	166	.22	161	.22	155	.24	161	.21
52	142	.23	151	.23	130	.26	140	.24
53	124	.25	127	.24	120	.25	121	.26
54	121	.25	119	.25	104	.28	118	.27
55	114	.28	118	.27	104	.29	113	.29
56	106	.29	112	.27	102	.30	105	.31
57	106	.30	104	.28	95	.32	98	.30
58	101	.30	105	.29	86	.33	98	.31
60	106	.30	98	.30	86	.34	94	.32
62	107	.30	103	.29	86	.35	97	.32

Day #5 (Depletion, 10 mg Vitamin B-6)

Minute of Exercise	Subject #1		Subject #2		Subject #3		Subject #4	
	HR	QT	HR	QT	HR	QT	HR	QT
0	43	.42	61	.34	49	.42	49	.39
1	97	.26	99	.28	104	.25	81	.34
2	107	.24	114	.27	104	.29	111	.31
3	104	.29	121	.26	111	.29	104	.30
4	103	.29	122	.26	122	.29	127	.30
5	114	.29	123	.27	119	.29	113	.29
6	114	.29	117	.27	121	.28	117	.28
8	120	.28	114	.26	120	.27	122	.29
10	115	.28	120	.26	124	.26	118	.29
12	118	.26	122	.25	121	.27	118	.29
14	118	.26	119	.25	118	.27	116	.29
16	117	.27	114	.25	126	.27	114	.29
18	118	.26	114	.25	126	.26	116	.29
20	117	.27	122	.25	117	.27	118	.29
22	124	.26	119	.26	117	.27	113	.29
24	112	.28	118	.26	120	.27	121	.29
26	118	.28	117	.27	120	.27	118	.29
28	116	.28	114	.26	122	.27	123	.28
30	117	.28	114	.27	114	.28	116	.28
32	125	.27	131	.25	136	.26	134	.27
34	143	.25	132	.24	157	.25	142	.27
36	149	.24	146	.22	160	.23	154	.24
38	154	.23	155	.22	161	.24	154	.23
40	158	.23	158	.21	164	.23	155	.24
42	163	.21	160	.20	169	.23	158	.23
44	164	.21	170	.21	167	.23	161	.23
45	164	.22	166	.20	167	.22	161	.22
46	161	.20	172	.20	174	.23	163	.23
47	164	.20	181	.20	174	.21	169	.22
48	174	.21	185	.19	177	.22	-	-
49	179	.20	186	.19	181	.20	-	-
50	177	.20	188	.19	179	.21	-	-
51	169	.21	170	.20	166	.22	154	.24
52	143	.23	148	.21	133	.25	122	.25
53	123	.24	144	.23	119	.25	113	.26
54	121	.27	131	.24	118	.26	112	.28
55	111	.28	122	.26	111	.27	104	.29
56	115	.28	121	.26	115	.28	102	.30
57	98	.28	109	.26	114	.30	104	.30
58	94	.29	107	.27	96	.30	93	.30
60	105	.30	97	.29	95	.32	93	.31
62	95	.30	103	.28	93	.33	89	.32

Day #6 (Loading, 10 mg Vitamin B-6) Minute of Exercise	Subject #1		Subject #2		Subject #3		Subject #4	
	HR	QT	HR	QT	HR	QT	HR	QT
0	38	.40	50	.36	48	.43	44	.43
1	89	.34	96	.30	107	.31	87	.35
2	97	.31	10	.30	90	.33	111	.33
3	105	.29	106	.28	103	.31	106	.30
4	110	.29	109	.28	114	.29	110	.31
5	115	.29	116	.28	107	.29	114	.31
6	119	.29	117	.28	114	.29	114	.31
8	121	.28	120	.27	124	.29	116	.31
10	124	.27	121	.27	127	.28	116	.31
12	125	.28	121	.26	129	.29	123	.31
14	126	.27	123	.25	128	.27	114	.31
16	124	.28	123	.25	120	.28	116	.30
18	120	.28	118	.26	120	.29	125	.29
20	119	.29	123	.25	120	.29	117	.31
22	121	.28	121	.26	128	.29	117	.31
24	120	.28	121	.27	117	.29	119	.29
26	123	.28	112	.28	121	.30	120	.30
28	127	.27	121	.27	122	.29	118	.29
30	122	.28	112	.28	127	.29	113	.29
32	144	.26	129	.27	144	.27	130	.29
34	153	.25	137	.24	151	.26	140	.27
36	158	.23	144	.25	157	.25	149	.25
38	161	.22	160	.23	161	.25	154	.23
40	158	.22	163	.23	161	.23	161	.23
42	161	.21	163	.25	161	.25	161	.23
44	160	.21	158	.23	161	.24	166	.23
45	163	.21	161	.24	161	.24	154	.23
46	161	.21	169	.22	166	.22	163	.23
47	166	.21	177	.21	170	.22	170	.22
48	169	.21	181	.21	177	.22	177	.22
49	175	.20	179	.21	181	.21	177	.22
50	177	.20	179	.21	183	.21	179	.22
51	164	.20	154	.24	167	.23	150	.23
52	127	.25	127	.24	141	.25	127	.26
53	114	.25	127	.26	127	.26	112	.30
54	111	.26	121	.27	113	.28	107	.30
55	110	.28	120	.25	114	.31	103	.30
56	110	.28	114	.27	108	.30	111	.32
57	104	.30	116	.28	106	.31	98	.31
58	93	.31	111	.28	105	.31	95	.33
60	104	.30	103	.28	97	.33	99	.33
62	101	.30	100	.29	94	.34	102	.32