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# Comparison of energy expenditure among three different cycling positions

Huw Ifor Griffiths
*The University of Montana*

# A COMPARISON OF ENERGY EXPENDITURE AMONG THREE DIFFERENT CYCLING POSITIONS

by

Huw Ifor Griffiths

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## ABSTRACT

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The purpose of this study was to investigate the economy of cycling among three different cycling positions. The positions were the: 1) recumbent, 2) dropped forward, and 3) upright. Economy was determined by measuring the amount of oxygen consumed during submaximal exercise on a bicycle ergometer. Fifteen subjects pedaled a bicycle ergometer at 1.0 kg and 2.0 kg of resistance while oxygen consumption was measured. The subjects exercised for a total of 10 minutes in each of the defined positions.

Statistical analysis consisted of a multiple analysis of variance (MANOVA) and the Tukey LSD method for post hoc analysis. A significant difference was discovered in the recumbent position for VE and RER between positions and for HR for position by workload. No significant difference was revealed for $VO_2$ $L \cdot min^{-1}$ or $VO_2$ $ml \cdot kg^{-1} \cdot min^{-1}$. The null hypothesis was accepted. The trained cyclists did not attain significantly greater cycling economy at submaximal $VO_2$ levels in the reclined position of recumbent cycling compared to the upright position or the dropped forward position required by the use of Scott DH Handlebars.

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# CHAPTER I

## Introduction

The energy expenditure of exercise is estimated by measuring oxygen consumption. The oxygen consumption of an individual will increase in direct response to an increase in the intensity of the exercise. If the exercise is performed at a light to moderate intensity, oxygen consumption rises quickly at the start (oxygen deficit), levels off, and remains at a relatively steady rate throughout the exercise period. When the exercise stops, oxygen consumption will decrease rapidly but does not return to resting levels immediately. The extra oxygen consumed, above a resting baseline during recovery, is approximately equal to the quantity of oxygen not consumed in the early adjustment to exercise and is referred to as oxygen debt (Brooks & Fahey, 1985). Energy expenditure can therefore be estimated from only one or two measures of oxygen consumption during the steady-rate phase of relatively moderate exercise. The oxygen consumption value of exercise can then be transposed to an energy value by using the approximate caloric transformation of 5kcal of energy generated per liter of oxygen consumed (McArdle, Katch & Katch, 1986).

The idea of efficiency is thought to be the association between input and resulting output. In terms of efficiency of human movement, it is the quantity of energy required to perform a specific task in relation to the actual work accomplished (McArdle, et al, 1986). By measuring the oxygen consumption response to graded submaximal exercise at specific work rates, it becomes possible to estimate the fraction of energy released that appears as external work. Efficiency of exercise refers to the mechanical efficiency. Mechanical efficiency is equal to the change in work divided by the change in the caloric equivalent of oxygen consumed (per liter). This value is reported as a proportion or percentage of total energy expended to produce external work.

An alternative and simple technique to confirm differences between individuals performing an identical exercise is to examine the economy of physical effort. This approach is also used during steady-rate exercise in which the oxygen consumed during the activity closely mirrors the energy expended (McArdle, et al, 1986). This factor of oxygen consumption becomes important for exercise activities of long duration. For activities of this nature success of the individual may depend on their aerobic capabilities and the oxygen requirements of the task. An individual with greater economy consumes less oxygen to perform the same task (McArdle, et al, 1986). Everything else being equal, a modification of training that improves the economy of effort results in improved performance.

Preceding studies have demonstrated that a difference exists for $VO_2$ values obtained during treadmill walking and running, arm cranking, bicycle ergometry, and bench stepping. This difference is attributed to the amount of muscle mass involved in the activity. Additional factors that influence the difference obtained are; physical fitness level, type of training, heredity, sex, body composition, muscle blood flow, and the metabolic capacity of specific muscle groups. In addition, it is well documented that the mechanisms of oxygen transport are affected by body position during work (Faria, Dix, & Frazer, 1978). This study examined one mode of exercise, bicycling, and three different body positions. The study examined the economy of cycling by having subjects perform three submaximal exercise tests in three different positions of bicycle riding. The three positions are as follows: 1) the upright position, 2) the dropped forward position (Scott DH Handlebars), and 3) the reclined position of recumbent bicycling.

## The Problem

The purpose of this study was to compare the difference in energy expenditure among the upright, dropped forward, and recumbent cycling positions.

## Delimitations, Limitations, and Assumptions

This study was delimited to trained male athletes between the age of 18 to 35 years.

The study was limited by the unregulated health habits of the subjects.

It was assumed that each subject followed the guidelines concerning activities prior to each testing session. It was assumed for each test the subject performed to the best of his abilities.

## Hypothesis

The null hypotheses were examined at a level of significance of $p<.05$:

The alternative hypothesis were that trained cyclists will attain significantly greater cycling economy at submaximum levels in the reclined position of recumbent cycling compared to the upright position or the dropped forward position required by the use of Scott DH Handlebars.

## Definition of Terms

Cycling economy - An individual with greater cycling economy will consume less oxygen to perform the same task (McArdle, et al, 1986).

Trained cyclist - A trained cyclist for this study met the following criteria: off season riding minimum of 150 miles per week; training season riding a minimum of 250 miles a week.

## Expected Results and Significance

The results of this study will have significance for use of the bicycle ergometer when measuring physiological parameters associated with exercise. The results may affect exercise prescription and workout variation for cycling in one of the specified positions.

# CHAPTER II

## Review Of The Literature

This study was concerned with the economy of cycling in three different cycling positions at two submaximal work loads. The purpose of this chapter is to present any previous findings which are related to this topic.

### Economy of Exercise

The physiological energy expenditure involved in common activities such as running, walking, or cycling can be influenced by a variety of biomechanical factors. Factors such as concentric and eccentric muscular contractions, transfer of energy, elastic storage and reuse of energy, and joint range of motion limitations can all change the mechanical energy of a limb segment (Williams, 1985). A further complication is the factor that there will always be some metabolic energy which does not show up as mechanical work, such as that involved in isometric contractions (Williams, 1985).

Bicycling has features which can effect economy of performance. Aerodynamic farings and recumbent bicycles can decrease the amount of work done against resistance. Additions such as these make it possible to improve economy since less work is done. A recumbent bicycle may allow the rider to be more effective and more efficient because of the postural changes consequent to the design (Cavanagh & Kram, 1985). Another example of the effect of equipment on economy is the bio-pace chainwheel. The elliptical chainwheel has been shown to improve economy by 2.4% (Henderson, Ellis, Klimovitch, & Brooks, 1977).

Energy expenditure estimates are measured via oxygen consumption. The type, intensity, and duration of the physical activity largely determines the amount of energy used. In regard to human movement, ease of effort in comparing trained athletes to the "less adept" athletes can easily be seen. Less adept athletes seem to expend considerable "wasted" energy when performing the same task. Therefore, to establish differences in energy expenditure, oxygen consumption is measured.

Economy of physical effort is useful during steady state exercise in which oxygen consumed during the activity closely mirrors the energy expended (McArdle, et al, 1986). At a standardized submaximal work load a person with a greater economy of movement consumes less oxygen to perform the same task. Economy is independent of total lean body mass (Cavanagh & Kram, 1985). A potential mechanical source for individual differences in economy between two individuals is differences in the distribution of the mass among limb segments (Cavanagh & Kram, 1985). Other anatomical variations may also have a potential impact on individual variations in economy. An athlete with lighter limbs running at precisely the same speed with precisely the same style and total body mass as one with heavier limbs will perform less physical work (Cavanagh & Kram, 1985).

Cardiac Output (CO)

The Fick equation states: $VO_2$ = CO * a-v $O_2$ difference, thus showing the relationship between CO and a-v $O_2$ difference. $VO_2$ is a measurement of the amount of oxygen consumed per minute. $VO_2$ increases during transition from rest to exercise. As the intensity of exercise increases so will $VO_2$ until $VO_2$ max is attained. Oxygen consumption increases during exercise because the CO and a-v $O_2$ difference increase. The higher oxygen transport capacity of athletes can be explained by a larger cardiac output achieved by increases in stroke volume and by a higher oxygen utilization. (Bevegard, Holmgren, & Jonsson, 1963).

Cardiac output (CO) is the amount of blood pumped by the heart per minute (Pollock, Wilmore, & Fox, 1984). CO is the product of stroke volume (the amount of blood pumped by the heart per beat) and heart rate (the number of times the heart beats per minute). Stroke volume increases steadily during exercise until about 25% of $VO_2$ max, and then levels off (Brooks, et al, 1988; McArdle, et al, 1986). Further increases in CO occur because of increased heart rate. At rest CO ranges from 5 to 6 liters per minute. While at maximal exercise CO can exceed 30 liters per minute (Brooks, et al, 1985; Fox et al, 1984; McArdle, et al, 1986). Therefore, the large increase in CO during exercise is a result of increased stroke volume and heart rate.

Research has shown that when at rest the transition from supine to upright position causes a decrease of the stroke volume (Cumming, 1972; McGregor, Adam, & Sekelj, 1961). This would, in turn, cause a decrease in cardiac output and ultimately a decrease in oxygen consumption. Stroke volume was discovered to be 40% smaller in the sitting position than in the supine position during bicycle exercise. Upon transition from rest to exercise, stroke volume in the sitting position increased to values slightly below those obtained during exercise in the supine position. Stroke volume was then constant, as in the supine position, during continued exercise with a heavier load. Bevegard, Holmgren, and Jonsson (1960) reported that only Musshoff found a significant increase of the stroke volume during work in the supine position.

As the intensity of exercise increases so does the amount of oxygen consumed. Arteriovenous oxygen difference (a-v $O_2$ difference) represents the amount of oxygen consumed by the tissues (Fox, et al, 1988). There are two factors that affect a-v $O_2$ difference during exercise. The first is the capacity of the body to divert a large portion of the cardiac output to working muscles. Certain muscles can temporarily compromise their blood supply considerably during exercise (McArdle, et al, 1986). This shunting increases the quantity of oxygen available for metabolism in the working muscle during exercise. The second factor is the ability of individual muscle cells to generate energy aerobically (McArdle, et al, 1986). Endurance training improves the metabolic capacity of specific cells. Mitochondria increase in size and number. The quantity of enzymes for aerobic energy transfer also increases (McArdle, et al, 1986). These two changes within the muscle increase the ability for aerobic production of ATP.

## Cardiac Output and Position

Changes in posture alter the cardiac response to exercise (Bevegard, et al, 1963; Reeves, Grover, Blount, & Filley, 1961). What becomes unclear are the types of circulatory changes associated with posture. Larger values of stroke volume have been achieved in the upright position (Bevegard, et al, 1960; Bevegard, et al, 1963; Cumming, 1972; Kubicek & Gaul, 1977; McGregor, Adam, & Sekelj,1961). A subsequent study questioned the degree of stroke volume change (essentially unchanged or increasing with work) during supine bicycle exercise (Galbo & Paulev, 1973). Granath and Strandell (1964) have found lower cardiac output and stroke volume values at rest and during exercise in the supine position. Further investigation reveals near maximal values of stroke volume can be observed at rest in the supine position and may increase only slightly during exercise (McArdle, et al, 1986). In contrast, Cumming (1972) and Jernerus, Lundin, & Thomson (1963) have shown increases in cardiac output for supine exercise.

Stroke volume increases during bicycle exercise for any posture, sitting or upright (Brooks and Fahey, 1985). The present concept on the stroke volume during bicycle exercise, which is accepted by most cardiophysiologists, can be summarized as follows: When the position is changed from supine to standing or sitting, there is a diminution in ventricular filling of the heart and a decrease in stroke volume (Astrand & Rodahl, 1978). The force of gravity counteracts the flow of blood to the heart, thus, reducing stroke volume and cardiac output. The effect of posture, supine and upright positions, on stroke volume and CO is especially apparent at rest where stroke volumes differed by as much as 40% (Bevegard, et al, 1963; Bevegard, et al, 1960; McArdle, et al, 1986; McGregor, et al, 1961). However, as the intensity of exercise in an upright position increases so does the stroke volume. The maximum stroke volume during intense exercise in the upright position nearly equals the maximum stroke volume in the supine position (McArdle, et al, 1986).

For top trained athletes and sedentary non-athletes, cardiac output increases linearly with oxygen consumption

(Holmgren, et al, 1960; McArdle, et al, 1986; Granath, Jonsson, & Strandell, 1961). In addition, a direct relationship exists between a-v $O_2$ difference and oxygen consumption. Even though position affects cardiac output, an increase in cardiac output directly affects the capacity to circulate oxygen.

Oxygen consumption in the supine position has been found to be generally lower on heavy but submaximal work loads ( Stenberg, Astrand, Ekblom, Royce, & Saltin, 1967; McArdle, et al, 1986). However, at the same oxygen uptake levels, heart rate was found to be higher in the upright position than supine position (Stenberg, et al, 1967). Femoral a-v $O_2$ difference was observed to increase sharply for mild exercise in the supine position, and further but smaller increases resulted with heavier exercise. Pulmonary a-v $O_2$ difference results were similar but changes during increased intensity were less dramatic. During submaximal exercise, oxygen transport relies more on increased oxygen extraction by tissues and less on total blood flow. During maximal exercise the oxygen transport relies more on increased blood flow and less on oxygen extraction from tissues (Reeves, et al, 1961).

Pulmonary Ventilation

Previous studies have indicated that the oxygen transportation system in humans is affected by body position during bicycle exercise (Bevegard, et al, 1963; Ekelund & Holmgren, 1964; Holmgren, et al, 1960; Holmgren, Mossfeldt, Sjostrand, and Strom, 1960; McGregor, et al, 1961; Reeves, et al, 1961; Stenberg, et al, 1967). Craig (1960) proposed that pulmonary ventilation (VE) during rest is increased in the forward lean body position. When the weight of the shoulder girdle is removed from the thoracic cage, the expiratory reserve volume increases, and increases again when the body is shifted from erect sitting to a slight forward lean (Faria, et al, 1978). A fifteen degree forward lean resulted in a 4% increase in expiratory reserve volume (Craig, 1960).

A comparison of heart rate, pulmonary ventilation, oxygen uptake, and work output between two different cycling positions was examined by Faria, et al, in 1978. The positions were: (1) sitting semi-upright with the hands on the uppermost portion of the handlebars; and (2) a deep forward lean, with the hands resting on the drop portion of the turned-down handlebars. A significant difference was found between the values of oxygen uptake and work output for the deep forward lean position. The difference was thought to be due to involvement of a larger muscle mass for the deep forward lean position. This position appeared to involve muscle of the arm, shoulder girdle, and low back.

Researchers generally agree that during exercise the size of the muscle mass involved increases oxygen uptake.

The acknowledgement of a difference in pulmonary ventilation due to the theory of reduced weight of the arms and shoulder girdle in the drop bar position. This illustrates that for the two positions examined the mechanisms of oxygen uptake are affected by body posture when cycling (Faria, et al, 1978).

Cycling vs Running

Extensive research in the area of exercise testing has been done to compare modes of exercise. One of the more common comparisons is to examine the relationship between treadmill running and cycle ergometry. Tests of this nature have shown that higher maximal oxygen consumption (max $VO_2$) values are generally obtained with treadmill running than on a bicycle ergometer. (Withers, Sherman, Miller, & Costill, 1981, Stromme, Ingjer,& Meen, 1977,McArdle & Magel, 1970, Ricci & Leger, 1983, Hermansen & Slatin, 1969, Hagberg, Giese, & Schneider, 1978). Several factors can influence the differences in the max $VO_2$ values obtained; such as physical fitness level, type of training, heredity, sex, body composition, and age (McArdle, et al, 1986). Leg force capacity, muscle blood flow, metabolic capacity of specific muscle groups, and the amount of muscle mass being engaged should be considered when attempting to explain the difference between the two modes of exercise (McArdle, et al, 1973; Powers & Beadle, 1985). Test subjects have stated feeling intense local discomfort in the thigh muscle during maximal work levels when pedaling a bicycle ergometer. This is thought to be a major factor limiting the subject's ability to perform further work on the bicycle ergometer and achieving max $VO_2$ (McArdle, et al, 1986).

Max $VO_2$ is generally considered the most valid indicator of the overall efficiency of the oxygen transport system in humans (Bouchard, Godbout, Mondor, and Leblanc, 1979). Maximal aerobic power as measured by maximal oxygen uptake is perhaps the most valid single physiological measure of the functional capacity of the cardiorespiratory system and of a person's ability to perform strenuous physical exercise (Taylor, Buskirk, & Henschel, 1955; Hermansen & Saltin, 1969; Astrand & Rodahl, 1978). Max $VO_2$ is the point at which oxygen consumption fails to rise despite an increased intensity or work load. Maximal exercise tests may include supine cycling, sitting cycling, arm ergometry, treadmill running and walking, and stepping on a bench. All are valid methods to measure max $VO_2$ because large muscle groups are used for these types of activities. Studies in this area have found that these work tests can yield different values for oxygen consumption (Bouchard, et al, 1979). Graded treadmill testing is generally considered to be the ideal instrument for determining maximal oxygen consumption in healthy subjects because the work output is easily determined and regulated.

Because the criteria for a max $VO_2$ test can be met by a trained cyclist on a bicycle ergometer the results obtained from such a test can be considered valid.

# CHAPTER III

## Methodology

### Subject selection

Fifteen males from the University of Montana were selected as subjects for this study. All fifteen subjects were trained cyclists.

### Introduction of subjects to the study

The subjects were given a brief orientation on the general purpose and procedures for the study. At this time the subjects were given a medical history and informed consent forms. These forms were signed, dated, and witnessed prior to testing. A tour of the Human Performance Laboratory was given and the subjects were shown all of the exercise testing equipment relevant to the study. The testing procedures were explained to reduce anxiety about unfamiliar procedures and remove confusion prior to testing. Appointments to begin the exercise tests were made at this time.

### Methods

Prior to the initiation of this investigation, approval from the University of Montana Institutional Review Board was obtained. In addition, each subject was given a verbal explanation of the investigation. Each subject was informed of the purpose of the study, any known risks or discomforts, the benefits to be expected, and his right to terminate any of the tests at any time he wished. Each subject expressed his understanding by signing a statement of informed consent (Appendix A) as required by the Institutional Review Board. In addition to the informed consent each subject completed a medical history form (Appendix B). The procedures used for this study closely followed the guidelines for exercise testing established by the American College of Sports Medicine (ACSM, 1986).

Descriptive data were obtained for each subject including age (yrs), height (cm), and weight (kg). Residual volume (mL) was predicted and, percent body fat was estimated by the hydrostatic weighing method. Laboratory testing for collection of the descriptive and experimental data was performed during January and February of 1989 in the Human Performance Laboratory at the University of Montana.

## Submaximal Cycle Ergometer Protocol

The exercise position for each submaximal test was determined at random prior to the subject's arrival at the laboratory. Upon arrival, resting blood pressure, height (cm), and weight (kg) were obtained.

The submaximal bicycle exercise test is designed to elicit a submaximal heart rate between 110 and 150 $b \cdot min^{-1}$. This heart rate range has the best linear relationship with $VO_2$ over a variety of ages and fitness levels (Pollock, Wilmore & Fox, 1984). For trained, active athletes, the risk of strain in connection with a submaximal work test is very slight. For male subjects, 900 kpm·min is sufficient to achieve the desired heart rate (Astrand & Rodahl, 1978).

Each subject sat quietly for 3 minutes for collection of resting data. Following the rest period each subject pedaled the cycle ergometer at 75 $rpm \cdot min^{-1}$ for 10 minutes. The exercise intensity was set at 1.0 kg for the first 5 minutes of the test. The resistance was then increased to 2.0 kg for the final 5 minutes. At the end of the 10 minute exercise period the frictional resistance was removed. The subject's heart rate was monitored until it dropped below 100 $b \cdot min^{-1}$ or came within 20 $b \cdot min^{-1}$ of the pre-test heart rate. Total time for the submaximal test was approximately 13 minutes.

Exercise Test Cycling Positions

Position #1 - The subject rode a Monark ergometer. The subject sat in the upright cycling position.

Position #2 - The Monark ergometer was equipped with Scott DH Handlebars. The subject was in the dropped forward position.

Position #3 - The subject rode a Modified Monark/Marcy R/em Recumbent Exercise Bike and pedaled in the reclined recumbent position.

Adjustment of saddle and handle-bar height was made to suit the comfort of the subject. Mechanical efficiency does not vary with the height of the handle-bar and saddle (Astrand & Rodahl, 1978). The most comfortable position, and in the case of very heavy work the most effective one is as follows: the front part of the foot is on the pedal and gives a slight bend of the knee-joint in the extended position (i.e. with the front part of the knee straight above the tip of the foot or in horizontal alignment for the recumbent position) (Astrand & Rodahl, 1978).

## Oxygen Consumption

Oxygen consumption was measured with a Beckman Metabolic Measurement Cart. Each subject breathed through a Hans-Rudolph respiratory mask. The exhalation port of the mask was connected to a mixing chamber. Expired air was pumped from the mixing chamber (500 $mL \cdot min^{-1}$) through a drierite cylinder into a Beckman OM-11 Oxygen Analyzer and a Beckman LB-2 Medical Gas Analyzer. Both analyzers were calibrated prior to each test using gas mixtures of known concentrations. The temperature and volume of remaining expired gases in the mixing chamber was measured by a volume transducer. Data from the transducers and analyzers are converted from analog to digital data and then transferred to a programmable calculator in the control panel. Minute by minute values are displayed as $VO_2$ ($mL \cdot min^{-1}$ and $mL \cdot kg^{-1} \cdot min^{-1}$), and VE ($L \cdot min^{-1}$), fractional concentration of oxygen and carbon dioxide of expired air ($F_ECO_2$ and $F_EO_2$) and respiratory exchange ratio (RER).

## Heart Rate

A Burdick Single Channel electrocardiogram was used to monitor the heart rate for all subjects during their initial submaximal test. A CM5 three lead configuration was used. Heart rate was recorded during the final 6 seconds of the gas collection period.

A Computer Instruments Corporation (CIC) Model 8799 heart rate monitor was used for subsequent tests. Heart rate was recorded continuously during the gas collection period. A heart rate monitor for monitoring exercise heart rate was used to allow ease of test adminstration after an initial rhythm strip had been obtained.

## Data Analysis

This study was a factorial experiment involving a single dependent variable, a specific physiological variable and two independent variables, position and work load. A multiple analysis of variance (MANOVA) was used to provide a method of testing for significant difference among the three independent cycling positions. Oxygen uptake ($VO_2$), minute ventilation (VE), respiratory exchange ratio (RER), volume of carbon dioxide ($VCO_2$), and heart rate (HR) were analyzed. The level of significance was set at $p<.05$. When a significant difference was found a post-hoc analysis using the Tukey LSD method ($p<.05$) was used to determine which position was significantly different.

CHAPTER IV

# Results And Discussion

## Results

Fifteen subjects participated in this study investigating the economy of cycling for three different cycling positions. The positions being; reclined recumbent, upright, and dropped forward. All subjects were able to meet the definition of a trained cyclist, which for this study meant they rode a minimum of 150 miles per week during the off season and a mimimum of 250 miles per week during the cycling season. Each subject completed 3 submaximal tests, one in each of the described positions. Additional data (Table 1) collected from all subjects included age (yrs), height (cm), weight (kg), and an estimate of percent body fat.

The results of a multiple analysis of variance (MANOVA) are illustrated in Tables 2-6. The statistical values for between positions, within workload, and the interaction of position by workload are given. A significant difference was found for VE, $VCO_2$, RER, HR, and $VO_2$ within workload (Tables 2-6). This was expected as the workload was changed during the exercise test. The statistical values for submaximal VE ($\underline{F}$ (2,28) = 6.43, $\underline{p}<.05$) are given in Table 2. Post hoc analysis using the Tukey LSD revealed that the recumbent position was significantly different ($\underline{p}<.05$) from the upright and dropped forward positions at 1.0 kg of resistance but not at 2.0 kg of resistance.

Table 1

# Measures of Central Tendency

| | MEAN | SD | RANGE |
|---|---|---|---|
| Body Fat (%) | 9.93 | 2.60 | 6.00 - 18.10 |
| Age (yrs) | 23.00 | 4.84 | 18.00 - 34.00 |
| Height (cm) | 171.73 | 4.09 | 166.00 - 179.00 |
| Weight (kg) | 73.09 | 5.23 | 64.54 - 86.36 |

Note. SD = Standard Deviation

Table 2

# MANOVA Data for VE

| VE (l/min) | DF | $F$ Score | P Probability |
| --- | --- | --- | --- |
| BETWEEN POSITIONS | 2,28 | 6.43 | .005* |
| WITHIN WORKLOAD | 1,14 | 201.67 | .000* |
| INTERACTION POSITION BY WORKLOAD | 2,28 | .51 | .606 |

Note. $p < .05$
* significance
DF = degrees of freedom

Table 3

MANOVA Data for VCO2

| VCO2 (l/min) | DF | F Score | P Probability |
|---|---|---|---|
| BETWEEN POSITIONS | 2,28 | 1.90 | .168 |
| WITHIN WORKLOAD | 1,14 | 494.02 | .000* |
| INTERACTION POSITION BY WORKLOAD | 2,28 | 1.44 | .253 |

Note. $p < .05$
* significance
DF = degrees of freedom

Table 4

# MANOVA Data for RER

| RER | DF | *F* Score | P Probability |
| --- | --- | --- | --- |
| BETWEEN POSITIONS | 2,28 | 4.39 | .022* |
| WITHIN WORKLOAD | 1,14 | 5.53 | .034* |
| INTERACTION POSITION BY WORKLOAD | 2,28 | .86 | .434 |

Note. $p<.05$
* significance
DF = degrees of freedom

Table 5

## MANOVA Data for HR

| HR (bpm) | DF | F Score | P Probability |
|---|---|---|---|
| BETWEEN POSITIONS | 2,28 | 1.57 | .225 |
| WITHIN WORKLOAD | 1,14 | 321.32 | .000* |
| INTERACTION POSITION BY WORKLOAD | 2,28 | 5.39 | .010* |

*Note*. $p<.05$
* significance
DF = degrees of freedom

Table 6

# MANOVA Data for VO2

| V02 (l/min) | DF | *F* Score | P Probability |
|---|---|---|---|
| BETWEEN POSITIONS | 2,28 | 1.39 | .265 |
| WITHIN WORKLOAD | 1,14 | 837.78 | .000* |
| INTERACTION POSITION BY WORKLOAD | 2,28 | 2.41 | .108 |

*Note*. $p < .05$
* significance
DF = degrees of freedom

The statistical values for submaximal for RER ($\underline{F}$ (2,28) = 4.39, $\underline{p}<.05$) are given in Table 4. Post hoc analysis revealed the recumbent position was statistically different ($\underline{p}<.05$) at 1.0 kg of resistance from the upright and dropped forward positions. No significant difference was found at 2.0 kg of resistance.

The statistical values for submaximal HR ($\underline{F}$ (2,28) = 1.57, $\underline{p}<.05$) are given in Table 5. A significant difference ($\underline{p}<.05$) for the interaction of position by workload was discovered for the dropped forward position at 1.0 kg but not at 2.0 kg of resistance.

The statistical values for submaximal $VO_2$ (L·min) are given in Table 6. No significant difference was found between positions or for position by workload.

## Discussion

### Minute Ventilation

Minute ventilation (Table 2) in this study was found to be significantly different ($\underline{F}$ (2,28) = 6.43, $\underline{p}<.05$) in the recumbent position at 1.0 kg of resistance. The post hoc ($\underline{p}<.05$) mean value for VE of 37.2 (L·min) was greater in the recumbent position. Figure 1 depicts the VE interaction for position by workload. Minute ventilation is greater in the recumbent position. Faria, et al (1978) reported

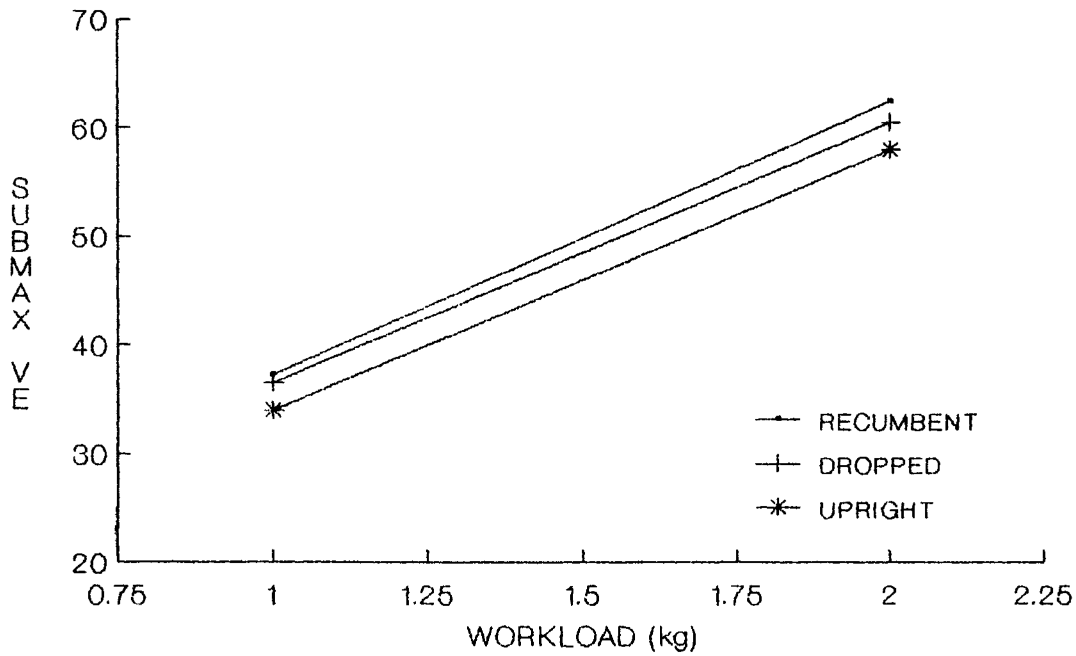


Figure 1. The VE comparison between positions. (VE, volume of air expired by the body in 1 minute.)

significant difference in VE for cyclists between the semi-upright and deep forward lean position. This was thought to be due to a greater weight load being placed on the thorax in the semi-upright posture. The deep forward lean posture appeared to reduce the weight of the arms and shoulder girdle from the thorax. This reduced weight was thought to ease chest expansion, thereby enhancing VE (Faria, et al, 1978). If the explanation of Faria, et al (1978) is correct it would help to explain the significant difference in VE for this study. If a smaller weightload is placed on the thorax by the arms and shoulder girdle in the reclined recumbent position, this may ease the chest expansion and cause higher values of VE.

When the inspired oxygen concentration of blood is reduced, ventilation increases. This is caused by stimulation of peripherial chemorecptors, which detect chemical changes in the blood. The chemical state of the blood is affected by arterial $PO_2$, $PCO_2$, acidity, and temperature (McArdle, et al, 1986). The peripherial chemorecptors act to stimulate ventilation in response to an increase in carbon dioxide, temperature, metabolic acidosis, or a fall in blood pressure (McArdle, et al,1986). If the exercise blood pressure is lower in the recumbent position than the other positions, it is possible that this reduced blood pressure could be an additional cause for the greater VE value achieved in the recumbent position. This is due to the fact that a fall in blood pressure can stimulate ventilation and cause large increases in minute ventilation (McArdle, et al, 1986).

An increase in carbon dioxide concentration causes an increase in minute ventilation. A greater but not significantly $VCO_2$ value ($\underline{F}$ (2,28) = 1.90, $\underline{p}<.05$) was also achieved in the recumbent position. This increase in $VCO_2$ could be an additional cause for the greater VE value discovered in the recumbent position.

An additional explanation is the incidence of entrainment, the alteration of breathing frequency to become "in step" with the exercise rhythm (Bechbache & Duffin, 1977). Bechbache and Duffin (1977) concluded that the rhythm of exercise is likely to affect the rhythm of breathing during moderate and steady state exercise. The subjects in this study may have been able to be more "in step" with the established cadence of the exercise protocol in the recumbent position.

No significant difference for VE was found at 2.0 kg of resistance between positions. The design of the recumbent ergometer combined with the unfamilarity of the cycling position required some of the subjects to brace themselves in the seat with their arms. Which created a static contraction. The contraction of the arms combined with the dynamic action of the legs pedaling the ergometer may have created static-dynamic exercise in the recumbent position.

A static-dynamic exercise builds intrathoracic pressure and impedes blood flow (Brooks,et al, 1985). This would in turn increase blood pressure. In addition, the increase of 2.0 kg resistance while still submaximal may have been great enough to increase exercise blood pressure in the reclined position. The exercise blood pressure may then have equaled the exercise blood pressure of the other positions. This increase in blood pressure may have affected the chemoreceptors which would then affect minute ventilation.

Respiratory Exchange Ratio (RER)

The RER (Table 4) was significantly different ($\underline{F}$ (2,28) = 4.39) p<.05 in the recumbent position at 1.0 kg of resistance. The post hoc mean value ($\underline{p}$<.05) was .94. RER is the ratio of $CO_2$ produced to $0_2$ consumed. This value was greater in the recumbent position and can be easily seen in Figure 2. Even though this study found that $VCO_2$ and $VO_2$ were not significantly different in the recumbent position, given that VE was significantly greater it is expected that RER would be greater.

RER is the metabolic gas exchange ratio (McArdle, et al, 1986). The mean value of .94 would indicate the composition of energy substrates to be nonprotein (McArdle, et al, 1986). This would be a blend of carbohydrates, fats, and proteins. The RER value examined here was collected during exercise and is not a result of excess $CO_2$ being

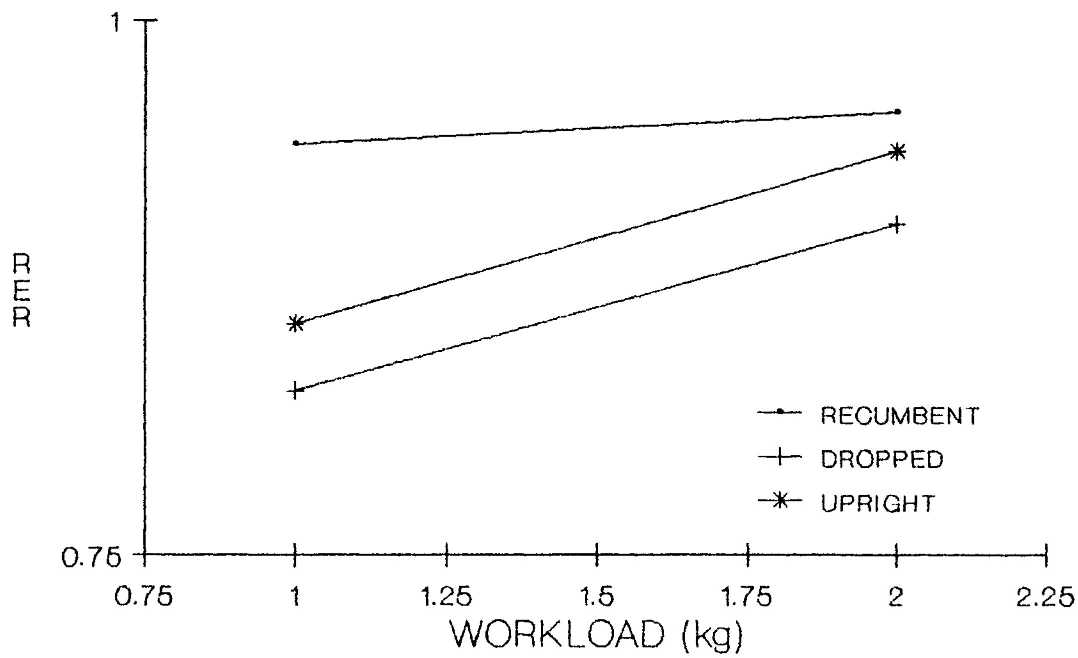


Figure 2. Respiratory exchange ratio between positions. (RER, the ratio of $CO_2$ produced to $O_2$ consumed).

"blown off" in which case RER may exceed 1.0. Excess $CO_2$ is "blown off" when the response of breathing is disproportionate to the metabolic demands of a particular situation (McArdle, et al, 1986). The significant difference revealed here was found at 1.0 kg of resistance. This workload is not believed to place a great energy demand on the test subject.

Heart Rate

Heart rate (Table 5) was significantly different ($F_{(2,28)} = 1.57$, $p<.05$) for position by workload. The heart rate in the dropped position was greater at 1.0 kg of resistance but not at 2.0 kg. The post hoc mean value for heart rate in the dropped forward position at 1.0 kg of resistance was 117 (bpm). Figure 3 shows the HR interaction for position by workload. It can be seen that heart rate is greater at 1.0 kg of resistance and not greater at 2.0 kg.

Scott DH handlebars are relatively new to the world of cycling and few if any of the cyclists in this study had never ridden a bike equipped with Scott DH Handlebars. This position was unfamiliar and uncomfortable to a majority of the subjects. This may be the reason for the significantly higher ($p<.05$) heart rate at 1.0 kg. A subject with poor mechanical efficiency will be underestimated in terms of max $VO_2$, because heart rate will be elevated (McArdle, et al,

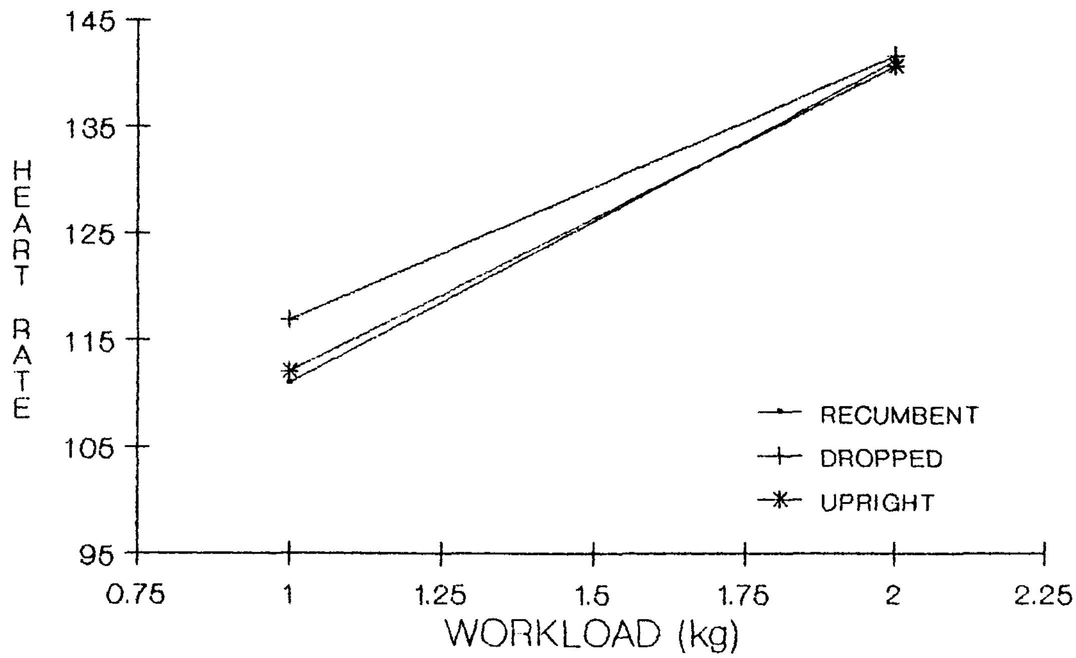


Figure 3. Exercise heart rate between positions. ( HR, the number of times the heart beats per minute).

1986). Factors other than oxygen consumption can influence heart rate. These factors can include temperature, emotions, food intake, body position, the muscle group exercised, and whether the exercise in continuous or stop-and go, or whether the the muscles are contracting isometrically or in a more rhythmic manner (McArdle, et al, 1986). When heart rate recorded during a task requiring upper body or static contraction is applied to heart rate-oxygen consumption line developed during running or cycling, the result would be an over prediction of the actual oxygen consumption. Therefore, this unconventional dropped forward position may have required greater effort by the subject not reflected in $VO_2$. No studies have examined the dropped forward position, as defined by this study. Therefore, no additional support for this hypothesis is available.

## Oxygen Consumption

This study found no significant difference ($\underline{F}$ (2,28) = 1.39,$\underline{p}$<.05) in energy expenditure among the defined cycling positions as measured by submaximal oxygen consumption (Table 6) at two different work loads (1.0 and 2.0 kg). This may be due to several factors. Williams (1985) examined the physiological energy expenditure of running, walking, and cycling. Factors such as concentric and eccentric muscular contractions, the transfer of energy, elastic storage and the reuse of energy, and joint range of motion limitations can change the mechanical energy of a limb segment. Each may involve a different amount of energy expenditure. No studies have examined energy expenditure as measured by oxygen consumption for the three positions defined in this study. Figure 4 illustrates the interaction of $VO_2$ L·min interaction for position by workload. It can be seen that $VO_2$ in the dropped forward and recumbent positions is almost identical at the same workloads. $VO_2$ in the upright position is slightly less but not significantly different ($F$ (2,28) = 1.39, $p$<.05).

Faria, et al (1978) did investigate oxygen uptake, inaddition to VE, HR, and work output between two cycling positions. The first position was sitting semi-upright on the saddle with the hands resting on the uppermost portion of the handlebars. The second position was sitting on the saddle while assuming a deep forward lean, with the hands resting on the drop portion of the turned-down handlebars (Faria, et al, 1978). A significant difference in oxygen uptake was found between a semi-upright and a deep forward lean position (Faria, et al, 1978). This difference was attributed to larger muscle mass involvement for the drop bar position. In contrast to Faria, et al (1978), McGregor, et al. (1961) examined the supine and sitting postures and found oxygen uptake for equal loads did not differ significantly. This study recorded similar results. The recruitment of the hamstrings in the recumbent position

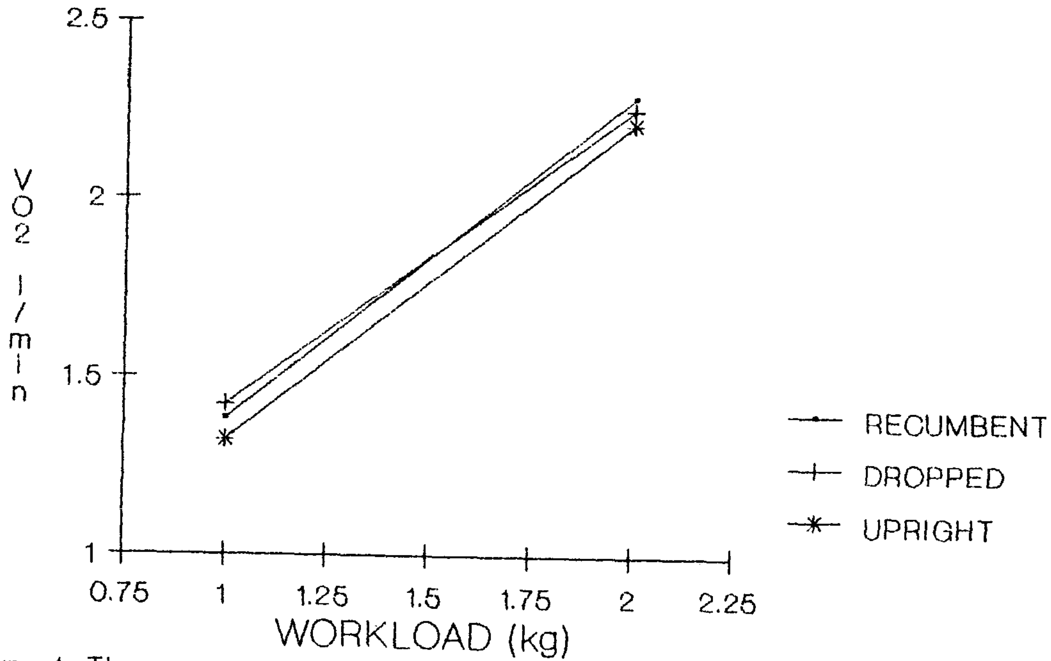


Figure 4. The energy expenditure between positions. (VO2,the amount of oxygen consumed in 1 minute).

could cause an equal involvement of muscle mass compared to the other positions during the exercise. This may cause similar values of oxygen consumption.

# CHAPTER V

## Summary, Conclusions, And Recommendations

### Summary

The primary purpose of this study was to examine energy expenditure as measured by oxygen consumption for three different cycling positions at a submaximal intensity. The subjects were 15 trained cyclists. All subjects rode the cycle ergometer in each of the defined positions for 10 minutes at a submaximal work load.

The literature review focused on five aspects relevant to this study; economy, cycling versus running, cardiac output, cardiac output versus position, and minute ventilation (VE) versus position.

A multiple analysis of variance (MANOVA) and a Tukey LSD post hoc analysis were performed for data analysis (Tables 2-6). Descriptive data for height, weight, percent body fat, and age are presented in Table 1. Post hoc analysis revealed a significant difference between positions for VE and RER in the recumbent position. A significant difference was revealed for HR for the interaction of position by workload in the dropped forward position.

This study found no significant difference in energy expenditure as measured by $VO_2$ among the three cycling positions.

## Conclusion

Based on the analysis of data at $p<.05$, the null hypothesis was accepted. These trained cyclists did not attain significantly greater cycling economy at submaximal $VO_2$ levels in the reclined position of recumbent cycling compared to the upright position or the dropped forward position required by the use of Scott DH Handlebars. This conclusion for a trained cyclists means that either position can elicit equal values of oxygen consumption for workloads of 1 and 2 kg in a laboratory situation.

## Recommendations

The following are recommendations offered by the researcher:

1) A field study should be designed to examine energy expenditure between the three cycling positions. This would provide an opportunity to examine the effect of body position with additional elements involved such as wind and terrain.

2) Use the information gathered from this investigation to establish training guidelines and goals for the recreational and trained cyclists. This study found that the energy expenditure was not significantly different among positions. Therefore, possible training guidelines and goals may be established to benefit the cycler who is unable to ride a standard bicycle in the upright or dropped forward position due to physical limitations.

# Appendix A

## Informed Consent

### Explanation of the Graded Exercise Test

You will perform three submaximal exercise tests on an exercise ergometer. The exercise intensity will begin at a level you can easily accomplish and will be advanced in five minutes to a second work load. We may stop the test at any time because of signs of fatigue or you may stop the test because of personal feelings of fatigue of discomfort.

### Risks and Discomforts

There exists the possibility of certain changes occurring the test. They include abnormal blood pressure, fainting, disorder of heart beats, and in rare instances heart attack or death. Every effort will be made to minimize these through the preliminary examination by observation during testing. Emergency equipment is available to deal with the unusual situations which may arise.

### Benefits

The information provided by the assessment of submaximal oxygen uptake provides a quantitative statement of an individual's capacity for aerobic energy transfer. As such, it is of one of the important factors determining one's ability to sustain high low intensity exercise for long periods of time.

Appendix A continued

Inquires

Any questions about the procedure used in the exercise test are encouraged. If you have any doubts or questions, please ask us for further explanations.

Freedom of Consent

Your permission to perform this exercise test is voluntary and you are free to deny consent if you desire.

Title 2, Chapter 9

In the event that you are physically injured as a result of this research you should individually seek appropriate medical treatment. If the injury is caused by the negligence of the University or any of its employees you may be entitled to reimbursement or compensation pursuant to the Comprehensive State Insurance Plan established by the Department Of Administration under the authority of M.C.A., Title 2. Chapter 9. In the event of a claim for such physical injury, further information may be obtained from the University Legal Counsel.

I have read this form and I understand the test procedures that I will perform. I consent to participate in this test.

__________________________ ________________________

Date Signature

# Appendix B

## MEDICAL HISTORY QUESTIONNAIRE

NAME:________________________________ S.S.#____________

AGE:__________ SEX:_________

NAME OF YOUR PHYSICIAN:__________________________

LIST THE DATE OF YOUR LAST:
PHYSICAL EXAM:_________ SURGERY:________ EKG:________

1. Have you been told by a doctor that you have or have had any of the following (please check the following)

| YES | NO | | YES | NO | |
|---|---|---|---|---|---|
| ( ) | ( ) | Rheumatic Fever | ( ) | ( ) | High Blood Pressure |
| ( ) | ( ) | An enlarged heart | ( ) | ( ) | Abnormal EKG pattern |
| ( ) | ( ) | Epilepsy | ( ) | ( ) | Diabetes |
| ( ) | ( ) | Heart or vascular disease | ( ) | ( ) | Hyperuricemia (High uric acid levels) |
| ( ) | ( ) | Metabolic disorders | ( ) | ( ) | Varicose veins |
| ( ) | ( ) | Heart Murmur | ( ) | ( ) | Stroke |
| ( ) | ( ) | Lung or Pulmonary disorders | ( ) | ( ) | Allergies specify:_______ |
| ( ) | ( ) | Thrombophlebitis Blood (blood clots) | ( ) | ( ) | Abnormally High Lipids (cholesterol or triglycerides) |

2. Please list any drugs, medication or dietary supplements PRESCRIBED by a physician that you are currently taking:

Drug ________________ For ________________ Dosage _________
Reactions:_______________________________________________

Drug ________________ For ________________ Dosage _________
Reactions:_______________________________________________

3. Please list any SELF PRESCRIBED drugs, medications or dietary supplements that you are currently taking:
Drug _______________ For ________________ Dosage ________
Reactions: ______________________________________________
Drug _______________ For ________________ Dosage ________
Reactions: ______________________________________________

Appendix B continued

4. Is there a history of heart disease, heart attack, elevated cholesterol levels, high blood pressure or stroke in your immediate family ( Grandparents, parents, brothers & sisters) <u>before the age of 60?</u> ( ) YES NO ( ) Number ______

5. Do you smoke now? ( ) YES ( ) NO
   a. If yes, how many cigarettes per day? ____
   b. If no, have you ever smoked? ( ) yes ( ) no
      A. If yes, how many cigarettes per day?
      B. How long ago did you quit? ______ years.

6. Are you currently under a great deal of stress either at work, school, or personally? ( ) yes ( ) no

7. Do you actively relieve stress through exercise, meditation or other methods? ( ) yes ( ) no

8. Are you currently on a regular exercise program? ( ) yes ( ) no If yes, please check the following.

Type of exercise: ( ) walking ( ) bicycling ( ) tennis
( ) aerobics ( ) swimming ( ) running
( ) other ____________________________

Frequency per week: ( ) 1-2 times/week ( ) 3-4 times/week
( ) 5 or more times/week

Duration (each day) ( ) <15 minutes ( ) 15-30 minutes
( ) 30-45 minutes ( ) >45 minutes

9. While exercising do you ever feel limited by ( if yes, state type of activity you are performing when this arises):

| | YES | NO | |
|---|---|---|---|
| a. Breathing | ( ) | ( ) | Activity:________________ |
| b. Chest, arm, or neck pain | ( ) | ( ) | Activity:________________ |
| c. Low back pain | ( ) | ( ) | Activity:________________ |
| d. Pain in leg, relieved by rest | ( ) | ( ) | Activity:________________ |
| e. Side aches | ( ) | ( ) | Activity:________________ |
| f. Lower leg pain<br>Front - Shin splints<br>Back - Achilles | ( ) | ( ) | Activity:________________ |
| g. Extreme long lasting fatigue | ( ) | ( ) | Activity:________________ |

I HEREBY CERTIFY THAT MY ANSWERS TO THIS QUESTIONNAIRE ARE TRUE AND COMPLETE AND TO THE BEST OF MY KNOWLEDGE I AM IN GOOD HEALTH.

Signed: __________________________________ Date: __________

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