ABSTRACT

IMPLEMENTATION OF CYCLIC EXERCISE PROTOCOL ON TWO STUDY GROUPS – AIDS AND INSOMNIA

by
Ujwala. G. Kalambur

Traditional exercise regimens are based on maintaining a prolonged increase in heart rate, followed by a single recovery period. The Cyclic Exercise Protocol is a novel protocol that is designed to create a series of parabolic waves of exercise and recovery. This study involves the implementation of this exercise protocol on two study groups namely AIDS and Insomnia. This exercise protocol involves short bursts of exercise lasting for 60 seconds or less followed by a period of complete aerobic recovery. The underlying principle of this exercise protocol is that rest, recovery and the body's natural rhythm are important to fitness and conditioning. The study involves the analysis of heart rate during cycles, focused breathing - breathing at a specific rate of 12 breaths per minute and circadian data - 24 hour biological rhythm of our body, for the AIDS population and only the heart rate data during cycles in case of Insomnia using Mathematica and Lab View. The subject populations as well as the physiological signals utilized in this study were obtained from the Philadelphia FIGHT Institute for AIDS and Harvard Medical School for Insomnia.

The parameters obtained during analysis of data from both study groups were statistically analyzed. There were significant results for the slope base parameter in case of the AIDS study and deep breath and downslope parameters in case of the Insomnia study. Therefore the cycles protocol with minimum exertion confers maximum benefits to our body.

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by
Ujwala. G. Kalambur

A Thesis
Submitted to the Faculty of
New Jersey Institute of Technology
In Partial Fulfillment of the Requirements for the Degree of
Master of Science in Biomedical Engineering

Biomedical Engineering Department

May 2003

APPROVAL PAGE

IMPLEMENTATION OF CYCLIC EXERCISE PROTOCOL ON TWO STUDY GROUPS – AIDS AND INSOMNIA

Ujwala. G. Kalambur

Dr. Stanley S. Reisman, Thesis Advisor — Date
Professor, Biomedical Engineering, NJIT, Newark, NJ

Dr. Tara Alvarez, Committee Member — Date
Assistant Professor, Biomedical Engineering, NJIT, Newark, NJ

Dr. David Kristol, Committee Member — Date
Professor, Biomedical Engineering, NJIT, Newark, NJ

BIOGRAPHICAL SKETCH

Author: Ujwala. G. Kalambur

Degree: Master of Science

Date: August 2003

Undergraduate and Graduate Education:

- Master of Science in Biomedical Engineering
  New Jersey Institute of Technology, Newark, New Jersey, 2003

- Bachelor of Science in Electronics and Communication
  Madras University – Chennai, India

Major: Biomedical Engineering

ACKNOWLEDGMENT

The author would like to express her sincerest gratitude to her advisor, Dr. Stanley Reisman, not only for his time and efforts in directing this research, but also for his valuable advice and guidance as a friend. His constant positive reinforcement and support were truly a source of motivation towards the achievement of this Masters' degree.

Thanks also to Dr. Tara Alvarez and Dr. David Kristol for their collaboration as members of the thesis committee.

Special thanks to the personnel at the Philadelphia FIGHT Institute, and Harvard Medical School, also to Ann Marie Petrock and Douglas Newandee for providing much needed assistance with the computer resources necessary for this research.

Last, but not least, the author is greatly indebted most of all to her parents, her sisters, family and friends for their strength, inspiration, support and divine intervention throughout the Masters' program. They are all very much appreciated and esteemed.

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CHAPTER 1

INTRODUCTION

1.1 Scope of Research

The scope of this research involves the implementation of a novel exercise protocol called the cyclic exercise protocol, which is aimed at improving the overall health of patients having AIDS and Insomnia.

The cyclic exercise protocol is designed to train exercise and recovery together as a cycle. The underlying principle of this exercise protocol is that rest, recovery and the body's natural rhythm are important to fitness and conditioning. The human body has inherent rhythms that occur with different periods and at different times as cycles. This exercise protocol that is designed to train exercise and recovery as a cycle, helps to improve the inherent rhythms of the body which play a key role in a person's health. The main objective of this research is to see if the implementation of the cycles protocol in people having AIDS and Insomnia helps them to recover from these diseases. The patient population under study includes people infected with AIDS and Insomnia. The state of health of the subject is evaluated by three methods namely the cycles baseline, the focused breathing session and the circadian rhythm session for the AIDS study and in case of Insomnia subjects, only the cycles baseline is evaluated and the exercise prescription is assigned to the subjects. The focused breathing and the circadian sessions are used to measure the progress made by the subject while undergoing the cycles session. The focused breathing also called the paced breathing requires the subject to breathe at a steady rate of 12 breaths per minute. The circadian rhythm is a biological clock that occurs every 24 hours and has its peak in the afternoon at around 4:00p.m. and a trough around 4:00a.m. The circadian rhythm is also made up of smaller cycles called the ultradians that have a period of 1.5 hours. Since most of the inherent body rhythms are in the form of cycles, the cycles exercise protocol is also designed for exertion and recovery together as a cycle, so as to improve these body rhythms, which are reduced in people with disease. The exercise data is analyzed using Mathematica 4.1 and the focused breathing data is used to analyze Heart rate variability, which is a non – invasive method to extract information on the autonomic nervous system.

1.2 Goals and Contributions for the Study

1. The goals of this research are
2. To determine the initial state of health of the subject through three baseline sessions namely, the focused breathing, the circadian rhythm and the cycles session for the AIDS study and only the cycles baseline inn case of Insomnia study.
3. To establish heart rate goals of the subjects after evaluating their health condition and their baseline session.
4. To collect the heart rate data from the subjects and use Mathematica as a tool for analysis.
5. To extract the parameters of interest using Mathematica, analyze them and plot graphs to view their behavior during the course of the cycles session.

6. To collect and analyze data for the focused breathing using frequency analysis. The data collected during focused breathing is used to evaluate heart rate variability.
7. To collect and analyze data for circadian rhythm using Mathematica to determine the shape of the circadian, i.e. to determine the peak and the trough and other parameters of interest.
8. To compare the subjects performing aerobics and subjects performing the cycles and evaluate their progress.
9. To statistically analyze the data and observe the trend of various parameters while the subjects go through their cycles session.

CHAPTER 2

PHYSIOLOGICAL BACKGROUND

2.1 Cardiovascular System

The cardiovascular system is sometimes called, simply, the circulatory system [1]. It consists of the heart, which is a muscular pumping device, and a closed system of vessels called arteries, veins, and capillaries. Blood contained in the circulatory system is pumped by the heart around a closed circuit of vessels as it repeatedly passes through the various "circulations" of the body. The vital role of the cardiovascular system in maintaining homeostasis is dependent upon the continuous and controlled movement of blood to reach every cell in the body. Regulation of blood pressure and flow must change in response to cellular activity. Consequently, numerous control mechanisms help to regulate and integrate the diverse functions and component parts of the cardiovascular system to supply blood to specific body areas according to need.

2.2 Physiology of the Heart

The heart is a hollow muscular organ about the size of a clenched fist. It is located in the thoracic cavity approximately midline between the sternum (breast bone) anteriorly and the vertebrae posteriorly. The heart has a broad base at the top and tapers to a pointed tip known as the apex at the bottom. It is situated at an angle under the sternum so that its base lies predominantly to the right and the apex to the left of the sternum.

Heart – Dual Pump

Anatomically the right and left sides of the heart function as two separate pumps. Figure 2.1 shows the heart and its chambers. The heart is divided into right and left halves and has four chambers; an upper and a lower chamber within each half. The upper chambers, the atria, receive blood returning to the heart and transfer it to the lower chambers, the ventricles, which pump blood from the heart. The vessels that return blood from the tissues to the atria are veins and those that carry blood away from the ventricles to the tissues are the arteries. The two halves of the heart are separated by the septum, a continuous partition that prevents the mixture of blood from the two sides of the heart. This separation is important because the right half of the heart is receiving and pumping oxygen poor blood while the left side of the heart receives and pumps oxygen rich blood.

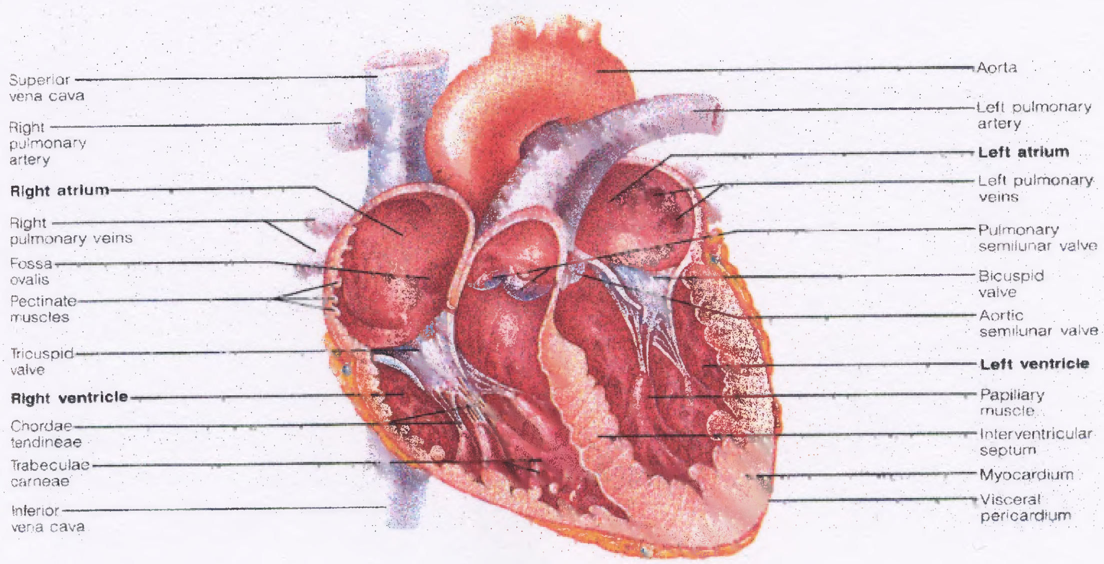


Figure 2.1 The Heart. (From E. N. Marieb, Human Anatomy and Physiology, 3rd ed. New York: The Benjamin/Cummings Publishing Company, Inc., 1995.)

The blood travels continuously through the circulatory system to and from the heart through two separate vascular (blood vessel) loops, both originating and terminating at the heart. The pulmonary circulation consists of a closed loop of vessels carrying blood between the heart and lungs, whereas the systemic circulation consists of a closed loop of vessels carrying blood between heart and other organ systems.

Blood returning from the systemic circulation enters the right atrium via large veins known as vena cavae. The deoxygenated blood returning from the body tissues enters the right atrium. In the lungs, the blood loses the extra carbon di-oxide and picks up the oxygenated blood and returns to the left atrium. The blood from the left atrium flows into the left ventricle and eventually into the aorta that supplies the oxygenated blood to all parts of the body. This is called the systemic circulation. Figure 2.2 showing the systemic and pulmonary circulation.

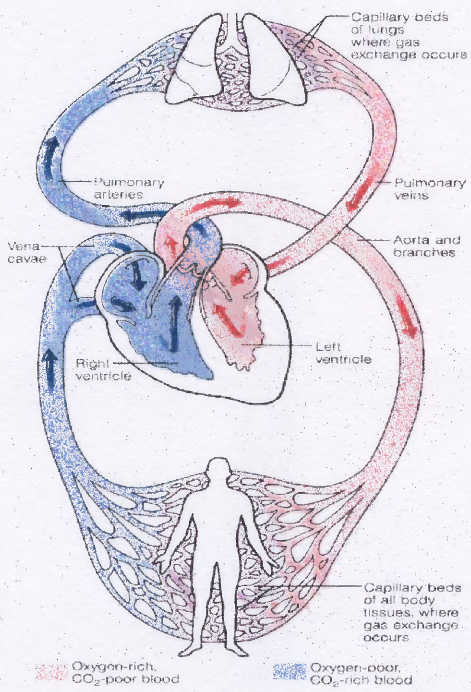


Figure 2.2 Systemic and pulmonary circulations.
The Systemic and Pulmonary Circulations. (From E. N. Marieb, Human Anatomy and Physiology, 3rd Ed. New York: The Benjamin/Cummings Publishing Company, Inc., 1995.)

2.3 Exercise Physiology

This research discusses the benefits of implementing the cyclic exercise protocol and hence its advantages on both diseased and healthy individuals. One of the major concepts in Exercise Physiology is that physical activity from the perspective of conferring health benefits may be the end goal of exercise, rather than physical activity for the purposes of achieving maximal levels of physical fitness for competition. Modest exercise such as walking, outdoor work, and stair climbing can contribute to achievable levels of physical fitness for the general population as well as "athletes" and confers the benefits of increased longevity. Since cyclic exercise is the exercise that confers maximum benefits to the body with minimum exertion, moderate exercise may be much more palatable to a patient than the idea of vigorous or strenuous exercise and may result in increased compliance with a recommended program.

Exercise generally takes two basic physiologic forms—dynamic exercise and static, or isometric, exercise—although most athletic activities are a variable combination of them. [7] E.g. Distance running.

Dynamic Exercise constitutes an alteration in the length of skeletal muscle with comparatively little change in muscle tension. [7]

Static Exercise is essentially the reverse—that is, a marked alteration in skeletal muscle tension with little or no change in muscle length. [7] E.g. Valsalva Maneuver.

2.3.1 Cardiac Output and Control

Cardiac output is the volume of blood pumped by each ventricle per minute. During exercise the cardiac output can increase to 20 to 25 liters/min. The two determinants of cardiac output are the heart rate and stroke's volume. The average resting heart rate is 70 beats per minute, and the average resting stroke's volume is 70 ml / beat producing an average cardiac output of 5 liters/min.[6]

Cardiac Output = Heart rate * Stroke volume

CO = 70 beats/min * 70 ml/beat

~ = 5 Liters / min.

The Stroke volume is defined as the difference between the End diastolic volume and the End systolic volume. The systole is the active contraction phase of the cardiac cycle. [9] The stroke volume is determined by three factors namely, Preload, Afterload and Contractility. This is the resting cardiac output. The difference between cardiac output at rest and the maximum volume of blood the heart is capable of pumping per minute is called the cardiac reserve. The reserve is a major determinant of exercise capacity in a population of normal subjects and patients with heart disease. [6]

2.3.2 Preload

Preload is the load (stretch, filling) on the ventricle before ejection. This is measured by end diastolic volume, and diastolic pressure and right atrial pressure and is regulated by the venous return to the heart. Physiologically, preload can be defined as the initial stretching of the cardiac myocytes (cells that line the walls of the heart) prior to contraction and is related to the sarcomere (smallest unit of the muscle fiber) length.

2.3.3 Afterload

Afterload can be viewed as the "load" that the heart must eject blood against. In simple terms, the afterload is closely related to the aortic pressure. A simple measure of afterload is mean arterial pressure.

2.3.4 Ionotropy -Contractility

Changes in stroke volume can be accomplished by changes in ventricular inotropy (contractility). Changes in inotropy are unique to cardiac muscle. A simple measure of cardiac contractility is Ejection Fraction (The amount left ventricle pumps out per beat is called the ejection fraction) Cardiac contractility increases with sympathetic stimulation. Changes in contractility alter the rate of force and pressure development by the ventricle and therefore change the rate of ejection.

Sympathetic stimulation increases the cardiac output by influencing the heart rate and the stroke volume. Sympathetic activity to the heart increases during exercise, when the working skeletal muscles need increased delivery of oxygen laden blood to support their high rate of ATP consumption. During the initial stages of exercise, increased cardiac output is due to an increase in both heart rate and stroke volume. When the level of exercise exceeds 40% to 60% of the individual's capacity, stroke volume has either plateaued or begun to increase at a much slower rate. Thus, further increases in cardiac output are largely the result of increases in heart rate. [6].

2.4 Exercise – Neural Review

2.4.1 Sympathetic Regulation of Heart Rate

Sympathetic nervous system innervates the AV node, the SA node and the atria and the ventricles of the heart and its regulation of heart rate is bought about by the combination of neural and hormonal pathways. Sympathetic efferent impulses travel from the brain via pre-ganglionic and postganglionic neurons to their target organs. At their terminus these postganglionic fibers release nor epinephrine or at the adrenal gland epinephrine. These catecolamines exert both a choronotropic (increased heart rate) and inotropic effect (increased contractility) on the heart.

2.4.2 Parasympathetic Regulation of Heart Rate

Parasympathetic nerve impulses reach the heart via the right and left vagus nerves, innervating the SA and AV nodes but only the atrial myocardium. Vagal efferent impulses trigger the release of a neurotransmitter, acetylcholine (ACh) at their synapses. (ACh) combines with myocardial muscarinic receptors which are the membrane-bound proteins that contains a recognition site for acetylcholine (ACh) and the combination of Ach with the receptor initiates a physiologic change of slowing the heart rate, which results in increased efflux of K+ ions and a reduced influx of Ca++ ions, the net result of which is to hyperpolarize the cell thus slowing the rate of depolarization and hence the heart rate. [8]. Figure2.3 shows the sympathetic and the parasympathetic nervous system.

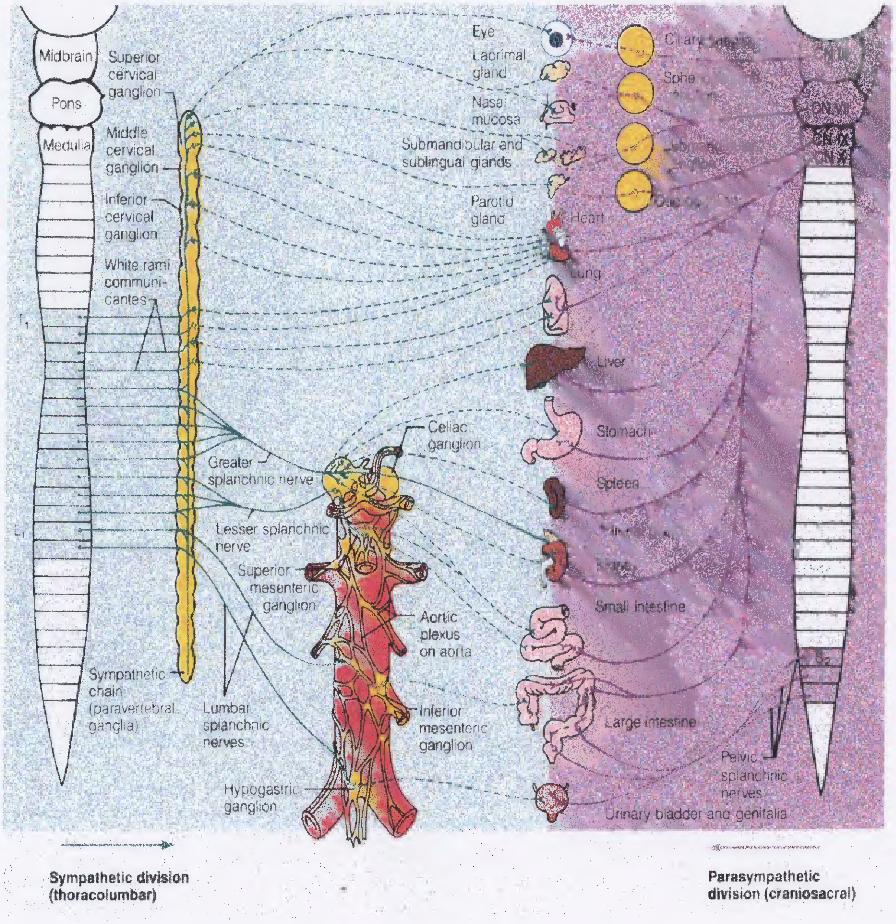


Figure 2.3 Sympathetic and parasympathetic nervous system.(From E. N. Marieb, Human Anatomy and Physiology, 3rd ed. New York: The Benjamin/Cummings Publishing Company, Inc., 1995.)

2.5 Behavior of the Heart During Exercise

The heart rate increases during exercise.

- The increase in heart rate is proportional to the workload.
- The maximum heart rate is estimated by subtracting a person's age from 220.
- The increase in heart rate is produced by an increase in sympathetic discharge, a decrease in parasympathetic (vagus nerve) discharge and an

increase in circulating catecholamines (epinephrine and nor epinephrine).

Stroke volume increases during exercise

- The increase in stroke volume is caused by an increase in ventricular contractility.
- The end diastolic volume (preload) does not change very much during exercise.

Cardiac output increases during exercise.

- Stroke volume may increase two fold.
- Heart rate may increase three fold.
- Cardiac output may increase six fold (from 5 L/min to 30 L/min).

Effect of exercise training on the cardiovascular system

At rest

- Reduced heart rate
- Increased stroke volume
- Increased end-diastolic volume
- Increased blood volume

At maximal workload

- Increased maximum stroke volume
- Increased maximum cardiac output
- Decreased maximum heart rate
- Increased maximum oxygen extraction
- Increase maximum oxygen consumption

Table 2.1 Cardiac Output during Light, Moderate, and Strenuous Exercise

Tissue	Resting (a-vO2difference)	Light (%)	Moderate (%)	Maximum (%)
Splanchnic	4.1	12	3	1
Renal	1.3	10	3	1
Cerebral	6.3	8	4	3
Coronary	14	4	4	4
Muscle	8.4	47	71	88
Skin	1.0	15	12	2
Other		4	3	1

Effects of Exercise on the Vascular System

Total peripheral resistance decreases during exercise.

- The arterioles perfusing exercising muscles are dilated by the metabolic byproducts that accumulate during exercise.
- The flow of blood through the exercising muscles and the number of capillaries through which the blood flows are increased.
- The resistance of the arterioles perfusing the skin decreases
- Cutaneous blood flowing increases
- The increased cutaneous blood flow contributes to the dissipation of the heat produced by the exercising muscles.
- The resistance of arterioles perfusing non-exercising muscles and other tissue beds, such as the kidney and gastrointestinal track, increase.
- Coronary vascular resistance decreases
- Coronary blood flow increases
- Delivery of oxygen to the myocardium increases to meet the demand.

2.6 Circadian Rhythm

Rhythms are intrinsic to possibly all life forms and occur at all levels of the life form. Circadian rhythms are cycles within a living organism, with a period of 24 hours. Complex behaviors such as the wake/sleep cycle have come under the control of these clocks, and these physiological clocks allow temporal ordering of gene and protein expression throughout the day and night (1–3). Most circadian behavioral and molecular rhythms have become dependent on the activity of these biological clocks [1]. Circadian rhythms have certain shared properties, regardless of the organism studied. The rhythms persist with a species-specific period, usually 22–25 hours, in constant darkness; this shows their endogenous origin. The phase of the rhythm can be reset (entrained) by pulses of daylight, and the period of the rhythm shows little tendency to vary with changes in temperature. [1] Eliminating clock function by tissue or gene ablation produces behavioral and molecular arrhythmicities that cannot be reversed by provision of environmental cycles. Thus, cellular pacemakers use environmental cycles to establish the phase of a biological oscillation, which in turn regulates the behavioral and physiological response. A graph of the 24-hour circadian rhythm is shown below.

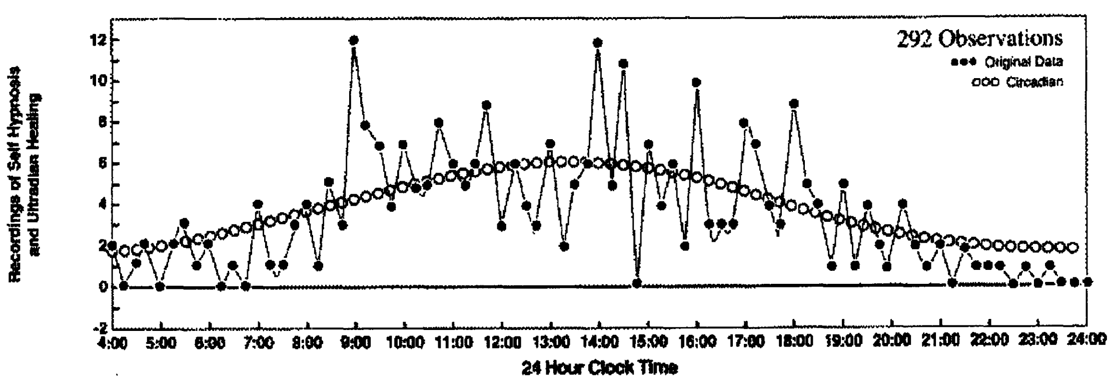


Figure 2.4 Graph of 24-hour circadian rhythm.

There are three intrinsic characteristics of biological clock they are 1) circadian rhythms can continue to run without environmental time cues (i.e. light), 2) circadian rhythms can be reset by changes in environmental conditions, and 3) the period of the circadian rhythm does not vary with the frequent changes of temperature in the environment. Behaviors associated with circadian rhythms range from courtship, visual capabilities, migration, phosphorylation, and photoperiodism. Synchronization of circadian oscillators with the outside world is called entrainment. Entrainment is defined as the tendency for two oscillating bodies to lock into phase so that they vibrate in harmony. It is also defined as a synchronization of two or more rhythmic cycles. The classic example shows individual pulsing heart muscle cells. When they are brought close together, they begin pulsing in synchrony. An ultradian rhythm is a biological rhythm that occurs with a frequency of less than 24 hours [2], which makes up the larger 24- hour wave. A classic example is the release of hormones into the blood. Most hormones are secreted into the bloodstream in a pulsatile manner rather than in a continuous fashion so hormones have a group of individual pulses making a smaller part of the overall circadian cycle. Growth hormone (GH) in humans, which has a period of 90 minutes, is a good example of this. Another type of circadian rhythm is the infradian rhythm which is a rhythm having a period much greater than 24 hours. An example would be the frequency of receptivity of female fireflies to male fireflies for mating [2]. Circannual is an annual rhythm. An example would be the annual migration of monarch butterflies from North America to Mexico.

The circadian clock has three major components: 1) A photoactive pigment (chromophore) for sensing light and transmitting light signals, 2) the circadian clock that oscillates every ~24-hrs, and 3) the genes controlled by the circadian clock to bring about the physiological and behavioral changes. It is generally believed that eye contains the photopigments for both visual (imaging) and circadian systems. Circadian axis is a name for a group of body parts comprised of the retinas, the pineal complex (of which the pineal gland is a photoreceptor, a circadian oscillator, and produces melatonin) and the suprachiasmatic nucleus (SCN), which is located in the region of the brain called the hypothalamus.

The circadian axis is common to all life forms both vertebrates and invertebrates [2]. Circadian axis is a name for a group of body parts comprised of the retinas, the pineal complex (of which the pineal gland is a photoreceptor, a circadian oscillator, and produces melatonin) and the suprachiasmatic nucleus (SCN), which is located in the region of the brain called the hypothalamus and they function as a unit. Investigation of the comparative physiology underlying these relationships has led to the hypothesis that all vertebrates share a common "circadian axis". [3] Environmental factors such as light and temperatures can entrain (synchronize) a cellular clock. Thus we conclude that the circadian rhythms and their components being wide spread throughout the body and occur at both the cellular and subcellular levels.

2.7 Cyclic Exercise Protocol

2.7.1 Dr. Dardik's Theory

From the earliest time, everything in nature has displayed rhythmic cycles like the light waves, sound waves, radio waves, and gravitational waves. And every second of our lives, our own heart valves open and close, for survival itself is based on maintaining these rhythms.[5]

There is a simple blueprint for human health: the collective, appropriate organization of the body's waves or rhythms, from the biochemistry to the heart, according to Dr. Irving Dardik's theory. Conversely, there is only one disease: the "flattening" of the body's waves. Because the human body's waves are fractal (self-similar repeating patterns at different scales), Dardik believes that shaping the larger waves in the body - such as the critically important heart wave (the combination of the heart's systolic and diastolic beats and the increase and decrease of the heart rate during exertion and recovery) - can organize the smaller waves, down to the cellular level. And because waves repeat themselves with "memory," he states, it is possible to help organize the body's rhythms with relatively brief training sessions that accelerate heart waves, and by synchronizing with the powerful circadian and other natural patterns, adding variability and preventing flattening [5].

Traditional exercise regimens are based on maintaining a prolonged increase in heart rate followed by a single recovery period. The efficacy of a cyclic exercise protocol designed to generate a series of parabolic waves of cardio acceleration lasting for less than a minute followed by recovery to a steady state was tested. In an observational study they studied the effects of this type of cyclic regimen, consisting of four to seven cycles per session, in a group of healthy women. Cardio respiratory fitness, autonomic function, and quality of life were assessed before and after 8 weeks of exercise, performed three days per week.

The implementation of a "cyclic" exercise protocol designed to train not only the activation phase, but also relaxation phase of exercise in a wave like or pulsatile fashion. The physiological importance of "training recovery" is derived from the concept that recovery itself is a dynamic process, mediated primarily by parasympathetic system. Therefore training recovery as well as activation may result in greater neuroautonomic plasticity, which may in turn enhance healthy function.

The cyclic protocol described here is tailored to measurements of an individual's HR during very short (<1 minute) periods of exercise, followed by variable of relaxation to a steady state. This preliminary observational study assessed the effects of a short 8-week course of cyclic exercise on selected measures of cardiovascular fitness and subjective perception of psychological well being in healthy adult women. [10].

2.7.2 Baseline Establishment

The state of health of the subjects is evaluated by three baselines namely the cycles session, focused breathing and the circadian session. Circadian Rhythm is the 24- hour rhythm of every individual. From the baseline cycles session the target heart rate is calculated for the individual subject for the succeeding cycles session. The circadian and the focused breathing sessions are measures of progress of the cycles session. This is not true in the insomnia study. The progress of a patient suffering from insomnia and undergoing the cycles, is measured by physiological and psychological tests conducted on them. The data obtained from focused breathing is used to evaluate heart rate variability.

2.7.3 Cycles Session

Traditional exercise regimens are based on increasing the heart rate to a target range determined by age and fitness and maintaining that level of activity for a sustained period. The cycles exercise protocol employs interval-type protocol, where there are alternating periods of exertion and recovery.

The cycles protocol is designed to train not only exercise but also recovery together as a cycle. The physiological importance of "training" – recovery is derived from the concept that recovery itself is a dynamic process, mediated primarily by the parasympathetic system. Therefore, training recovery as well as activation may result in greater neuro- autonomic plasticity, which in turn may enhance healthy function. The cyclic exercise protocol is designed to generate parabolic waves of exercise and recovery. A single cycle consists of short burst of exercise followed by a period of cardiovascular recovery. The "Cycles" are performed in sets of three to seven cycles, three times a week. Each cycles session takes between 30 - 45 minutes involving 3-7 minutes of exertion per cycles session and the total amount of exertion is no more than 40 minutes a month. During a cycle, subjects are required to exercise at a predetermined exertion level and reach a defined heart rate goal determined by the baseline session. So the cycles program, with minimum exertion can be performed anywhere.

Thus the cycles program with short bursts of exercise and recovery as a wave helps in training the larger 24-hour rhythm of the body thereby improving the overall health of an individual.

2.8 Insomnia

"Insomnia" describes any episode of unrefreshing sleep, difficulty falling asleep, frequent awakenings, or waking up too early in the morning.

Sleep is essential for mental and physical restoration. It is a cycle with two separate states: rapid eye movement (REM), the stage in which most dreaming occurs; and non-REM (NREM). Four stages of sleep take place during NREM: stage I, when the person passes from relaxed wakefulness; stage II, an early stage of light sleep; stages III and IV, which are increasing degrees of deep sleep. Most stage IV sleep (also called delta sleep) occurs in the first several hours of sleep. A period of REM sleep normally follows a period of NREM sleep. [4]

Insomnia afflicts about a third of the adult population and is associated with increased mortality, psychiatric disturbances, and decreased work productivity (1,2). Because sleeping pills--the most common treatment for insomnia--are associated with increased mortality (2), medication tolerance and dependence, and a host of negative side effects (3), they are seldom recommended for long-term use. Hence, clinicians and patients have shown increased interest in cognitive and behavioral strategies for improving sleep. [11]

2.8.1 Causes of Insomnia

Transient insomnia is often caused by a temporary situation in a person's life, such as an argument with a loved one, a brief medical illness, or jet lag. When the situation is resolved or the precipitating factor disappears, the condition goes away, usually without medical treatment.

Chronic insomnia usually has different causes, and there may be a contribution of two more. These include:

- A medical condition or its treatment, including sleep apnea
- Use of substances such as caffeine, alcohol, and nicotine
- Psychiatric conditions such as mood or anxiety disorders
- Stress, such as sadness caused by the loss of a loved one or a job
- Disturbed sleep cycles caused by a change in work shift
- Sleep-disordered breathing, such as snoring
- Periodic jerky leg movements (nocturnal myoclonus), which happen just as the individual is falling asleep
- Repeated nightmares or panic attacks during sleep.

Another cause is excessive worrying about whether or not a person will be able to go to sleep, which creates so much anxiety that the individual's bedtime rituals and behavior actually trigger insomnia. The more one worries about falling asleep, the harder it becomes. This is called psycho physiological insomnia. [5]

2.8.2 Symptoms of Insomnia

People who have insomnia do not start the day refreshed from a good night's sleep. They are tired. They may have difficulty falling asleep, and commonly lie in bed tossing and turning for hours. Or the individual may go to sleep without a problem but wakes in the early hours of the morning and is either unable to go back to sleep, or drifts into a restless unsatisfying sleep. This is a common symptom in the elderly and in those suffering from depression. Sometimes sleep patterns are reversed and the individual has difficulty staying awake during the day and takes frequent naps. The sleep at night is fitful and frequently interrupted. [5]

2.8.3 Prevention of Insomnia

Prevention of insomnia centers on promotion of a healthy lifestyle. A balance of rest, recreation, and exercise in combination with stress management, regular physical examinations, and a healthy diet can do much to reduce the risk.

Walking is also recommended. However, exercise should be done no more than three hours before bedtime. Drinks that contain caffeine such as coffee, tea and colas, chocolate (which contains a stimulant), and alcohol, which initially makes a person sleepy but a few hours later can be a stimulant should all be avoided. Maintaining a comfortable bedroom temperature, reducing noise, and eliminating light are also helpful. Watching television should be avoided because it has an arousing effect. Weil wrote that the news with its "murder, mayhem, and misery" is a major source of turmoil. Exercise, relaxation, and nutrition should be considered ongoing preventive measures. While life will bring unexpected stresses and pressures, the person who is familiar with relaxation techniques will be more prepared to cope with insomnia. [4]

2.9 Heart Rate and Heart Rate Variability

2.9.1 Physiology of Changes in Heart Rate

Change in heart rate is sensitive to changes in body temperature, plasma electrolyte concentrations and hormone concentrations [10]. However, the most important influence of beat-to-beat variations of heart rate comes from the autonomic nervous system. More specifically, sympathetic activity increases heart rate, whereas activity in the parasympathetic (vagus) nerves causes the heart rate to decrease. Due to considerably more parasympathetic activity to the heart than sympathetic activity in the resting state, the normal resting heart rate is below the inherent rate of 100 beats/minute.

The autonomic nervous system innervates the heart in a number of places. The sympathetic nervous system terminates at the SA node, the conduction system, atrial and ventricular myocardium, and coronary vessels. The parasympathetic fibers terminate in the SA and AV nodes, atrial and ventricular musculature, and coronary vessels. Interplay between the two systems will cause the heart to speed up or slow down, depending on which system is more active. [13].

Perhaps the most important site of innervation of the autonomic nervous system on the heart occurs at the SA node. As matter of fact, the SA node possesses an inherent discharge rate, often referred to as the pacemaker potential. The pacemaker potential is a slow depolarization of the cells of the SA node. The innervation of the sympathetic and parasympathetic nervous system on the SA node changes the characteristics of depolarization within the SA node cells, thus changing heart rate. Table2.2 shows the autonomic effects on selected organs of the body.

Table 2.2 Autonomic Effects on Selected Organs of the Body (From A.J. Vander, J.H. Sherman, and D.S. Luciano, Human Physiology, 1994)

Effector Organ	**Effect of Sympathetic Stimulation**	**Effect of Parasympathetic Stimulation**
Eyes		
Iris muscles	Contracts (dilates pupil)	Relaxes (constricts pupil)
Ciliary muscle	Relaxes (flattens lens)	Contracts
Heart		
SA node	Increases heart rate	Decreases heart rate
Atria	Increases contractility	Decreases contractility
AV node	Increases conduction velocity	Decreases conduction velocity
Ventricles	Increases contractility	Decreases contractility slightly
Arterioles		
Coronary	Dilates (β_2); constricts (α)	Dilates
Skin	Constricts	None
Skeletal muscle	Dilates (β_2); constricts (α)	None
Abdominal viscera	Dilates (β_2); constricts (α)	None
Salivary glands	Constricts	Dilates
Lungs		
Bronchial Muscle	Relaxes	Contracts
Stomach		
Motility, tone	Decreases	Increases
Sphincters	Contracts	Relaxes
Secretion	Inhibits (?)	Stimulates

2.9.2 Heart Rate Variability as a Measure of Autonomic Function

Changes in heart rate usually involve the reciprocal action of the two divisions of the autonomic nervous system. An increased heart rate is the result of reduced parasympathetic tone and a concomitant increase in sympathetic activity. A decrease in heart rate is usually the result of increased parasympathetic tone and a simultaneous decrease in sympathetic tone. Therefore, changes in heart rate reflect the action of the sympathetic and parasympathetic nervous systems on the heart. However, under certain conditions, it is possible for heart rate to change by activity of only one division of the autonomic nervous system, independent of the other division, rather than reciprocal changes in both. [22]

Initially, the effect of the autonomic nervous system on the heart was estimated by utilizing the traditional technique of average heart rate [22]. As a reference, the average heart rate was measured under normal resting conditions. Then the average heart rate was measured under the administration of drugs. The drugs used were atropine, which blocks the effects of the parasympathetic nervous system, and propranolol, which masks the effects of the sympathetic nervous system. A qualitative assessment can then be made of the autonomic nervous system by comparing the reference heart rate to the heart rate while under the administration of the drugs. This method looks at the average over time of heart rate. However, when the ECG is looked at on a beat-to-beat basis, rather than over a period of time, fluctuations in the heart rate are observed [22]. Recent research indicates that fluctuations in heart rate are a healthy sign. In fact, one hypothesis is that the larger variations in the heart rate correlate to a healthier autonomic nervous system.

By contrast a number of physiologic and disease states produce alterations in autonomic function, which reduce the variability in heart rate [23].

2.9.3 The Electrocardiogram

The electrocardiogram (ECG) is primarily a tool for evaluating the electrical events within the heart. The action potentials of cardiac muscles can be viewed as batteries that cause charge to move throughout the body fluids. These moving charges, or currents, represent the sum of the action potentials occurring simultaneously in many individual cells and can be detected by recording electrodes at the surface of the skin [10]. Figure

2.8 illustrates a typical normal ECG recorded between the right and left wrists for one heartbeat.

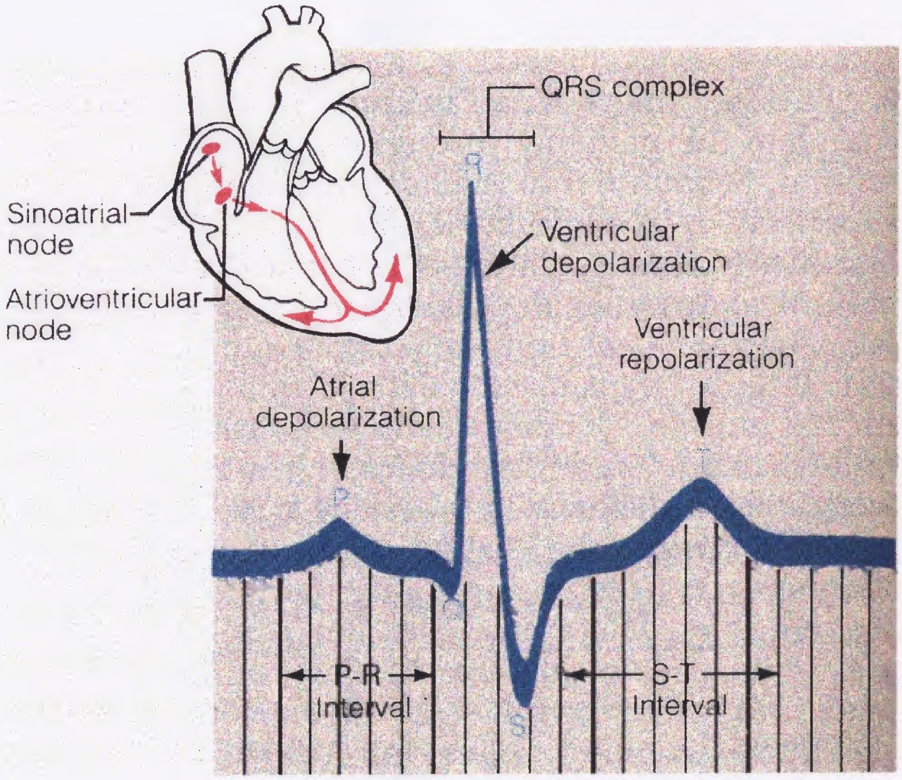


Figure 2.5 The electrocardiogram. (From E. N. Marieb, Human Anatomy and Physiology, 3rd ed., 1995.)

The first deflection, the P wave, corresponds to the current flow during atrial depolarization (contraction). The second deflection, the QRS complex, is a result of ventricular depolarization. The third and final deflection is the T wave. The T wave is a result of ventricular repolarization (relaxation). It should be noted that atrial repolarization is usually not evident in the ECG because it occurs at the same time as the QRS complex.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The experimental protocol yielding the data utilized for this study was performed at the Philadelphia FIGHT Institute from an on going pilot study. The data acquired from the subjects during the study was Heart Rate, Paced Breathing, Deep Breath and Circadian Rhythm. There were physiological data recorded, such as blood pressure and tests that monitored the immune system of the subjects involved in the study.

This section presents the implementation of the exercise protocol in AIDS subjects, including subject selection criteria, protocol implementation and data acqusition.

3.2 Subject Selection for AIDS

The pilot study consisted of 11 subjects infected with AIDS and subjects above 18 years was eligible unless their history revealed any of the following: smoking, chronic disease, chronic drug or medication use, musculoskeletal limitations or participation in a structured exercise program. Each subject was required to sign a consent form, approved by Philadelphia FIGHT IRB.

There were 57 subjects who participated in the study and were divided into three groups. A group of subjects 11 subjects did the cycles exercise; the second group of 12 subjects did aerobics and the third group consisting of 12 subjects who was the control or the sedentary group. The third group was used as a control for physiological and quality of life questionnaires. The heart rate data acquired during the aerobics exercise were compared with the heart rate data acquired during the cycles protocol. The subjects were required to come in at specific times of the day and were requested to refrain from any caffeine and meal intake for three hours prior to testing. Upon arrival, subjects were briefed on the cycle baseline exercise test protocol, familiarized with the equipment and instructed on the relaxation response.

3.3 Study Design for AIDS

The evaluation of the state of health of the subjects includes three baseline sessions namely, the Cycles Program session, the Focused Breathing session and the Circadian Rhythm session. The focused breathing and the circadian sessions were performed prior to the cyclic exercise regimen, at the end of 8th, 16th, and 24th week and after the completion of the program. The data collected during the focused breathing session is used to evaluate the heart rate variability of the subjects and the data collected during the circadian rhythm session, is used to estimate the overall health of the subject. The subjects are required to fill out a standard questionnaire to assess the subjective sense of well – being. Based on the cycles baseline session, the target heart rates – heart rate to be achieved by each subject undergoing the cycles, is determined. In case of aerobics study, the target heart rate was determined using the same formula used in the cycles. At the completion of the cycles session, physiological tests like, lymphocyte counts and differentials, cortisol levels, liver enzymes, lipid panel, testosterone were conducted The target heart rates for the aerobics were calculated using the formula

$$\text{Target Heart Rate} = 220 - \text{the age of the person} * 0.7 \qquad (3.1)$$

3.4 Protocol Description

One significant way to enhance the natural rhythms of the body is to create them ourselves. Much of our natural activity is rhythmic, from laughter to running. Because the human body's waves are fractal (self-similar repeating patterns at different scales), shaping the larger waves in the body - such as the critically important heart wave (the combination of the heart's systolic and diastolic beats and the increase and decrease of the heart rate during exertion and recovery) - can organize the smaller waves, down to the cellular level.

Since waves repeat themselves it is possible to help organize the body's rhythms with relatively brief training sessions that accelerate heart waves, and by synchronizing with the powerful circadian and other natural patterns, adding variability and preventing flattening. [13]. Heart rate (HR) recovery after exercise has long been used as a marker for physical fitness, possibly related to the high vagal tone associated with fitness and good health [14]. Exercise appears to be a truly good medicine, but only if the recovery side of the equation is addressed with equal training considerations. An emerging form of exercise called the cycles exercise is discussed in detail. The cycles exercise program is designed to generate a series of parabolic waves of cardiovascular exercise and recovery. It is embedded within a holistic lifestyle program called LifeWaves®, designed to adjust the circadian rhythm (i.e., the body's natural 24-hour "clock,"), which organizes all biological processes, including metabolic rises and dips, blood pressure peaks and valleys, hormonal releases, etc. [12]

A single cycle consists of short burst of exercise followed by a period of complete recovery. The subjects are required to follow the relaxation response to facilitate the recovery period. This increases the parasympathetic nervous system activity and hence may accelerate the increase in parasympathetic nervous system activity during recovery. The cycles are performed in sets of four to seven and at specific times of the day. The study is designed such that the cycles performed in the afternoon sessions required more exertion than the morning session because the work performance typically increases in the afternoon. This is critically important because the body chemistry is different at different times of the day, month and year. The exertion levels, the numbers of cycles per session and target heart rates vary throughout the month. The subjects are given target heart rates shown in Table 3.1 and are required to achieve those goals. These target heart rates are determined by the baseline cycles session.

Table 3.1 Target Heart Rates and Exertion Level for Subject C10

TargetHeartRates In Beats/Min	**Exertion Scale**
131	(2)
142	(3)
156	(4)
165	(5)
No goal	(5)

1) Exertion Scale:
2) Easy Pace
3) Accelerate to Moderate Pace
4) Accelerate to Moderately Vigorous Pace

5) Accelerate to Vigorous Pace (Maximum Effort}

6) Maximum effort from the start of the cycle to the finish (Spike)

7) No Goal: Do a spike (maximum effort from the start of the cycle to the finish), but stop if your heart rate stops rising, if your heart rate drops, if you become tired, or if you have gone for a full minute.

There are two types of files namely five second averaged heart rate and Interbeat interval files. The five second averaged heart rate files, have their data averaged every 5 seconds and the Interbeat interval files records the distance between an R-R wave in an ECG signal in milliseconds. The data files used in AIDS study are the Interbeat interval files.

3.5 Cycles Testing

Subjects are requested to refrain from caffeine for three hours prior to cycles testing. The subjects are briefed on the exercise protocol. During the first cycle of the baseline-testing phase, the subjects are required to exercise at an easy pace (3 on a 10 point Borg Scale-explained in the appendix is defined as a simple method of rating perceived exertion (RPE) used by coaches to gauge an athlete's level of intensity in training and competition) until the heart rate stabilizes. The heart rate is said to have stabilized when it is varying +/- three beats over 15 seconds, which occurs less than one minute of exertion. The heart rate data was collected using a Polar NV HR monitor watch and chest strap (Polar Electro Inc., Woodbury NY) and then downloaded to a computer. The cycles session was monitored by a trainer. The subject took a deep breath followed by a button push, indicating the time at which the subject actually takes the deep breath. The subject, by taking the deep breath initiates the relaxation response. When the subject recovered, he again took a deep breath, indicating by means of a button push and recovered when the heart rate became stable.

The subject performed cycles two three and four in a similar manner, but with increased level of exertion. The final cycle of the baseline test was used to determine the peak heart rate for that particular cycles session. The final cycle usually was vigorous consisting of brief exertion (9 on a 10 point Borg Scale), until the peak heart rate is reached (< 1 minute). This vigorous exertion is usually achieved by exercising on the trampoline using hand weights (2-3pounds) to assist the subjects reach high heart rates within the allotted 60 seconds.

Then the subject began the final recovery cycle. Once the cycles baseline testing had been completed, the subject started the cycles regimen consisting of four-seven cycles per day, and three days per week for 16 weeks. A trainer monitored the whole cycles session. Target heart rates were calculated as percentages of the peak HR determined from the baseline session. The subjects underwent the cycles session three times a week. Each week had three sessions on Monday, Wednesday and Friday. The target heart rate goals were matched to the appropriate files according to the sessions and the date. After four weeks of assessment if the subject had exceeded the target heart rate in the final cycle of the final session by more than five beats per minute, he was moved to the next higher target. Figure 3.1 shows the graph of the cycles performed by a specific subject.

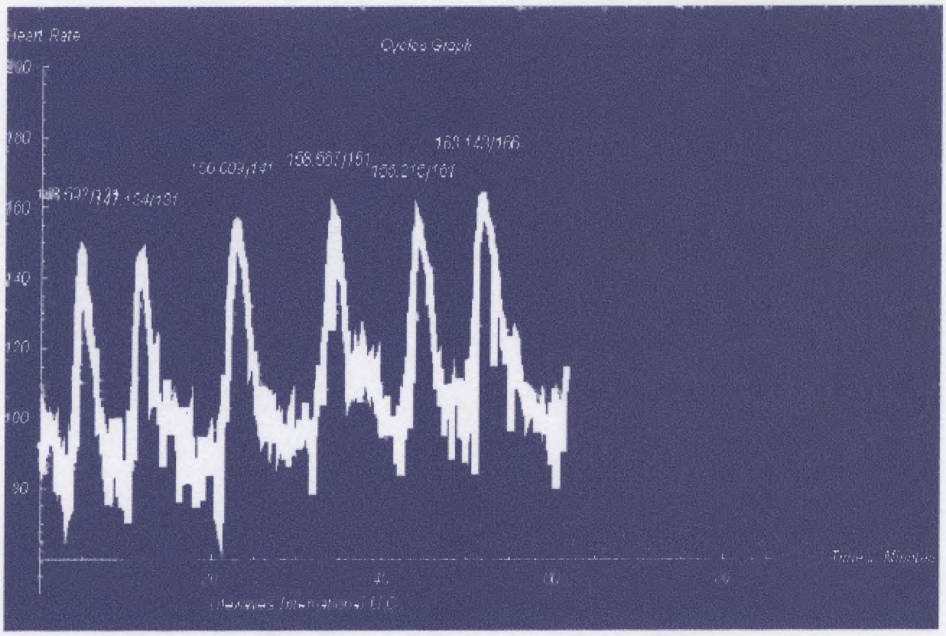


Figure 3.1 Graph of cycles performed by subject C10.

3.6 Heart Rate Variability

The oscillation in the interval between consecutive heartbeats as well as the oscillations between consecutive instantaneous heart rates is heart rate variability [15]. This variability, is mainly affected by respiration and is called as the Respiratory Sinus Arrhythmia, is predominantly mediated by the vagus nerve and is reduced or abolished by vagatomy (the surgical cutting of the vagus nerve)[16]. The amplitude of the beat-to-beat variation is a clinical measure of autonomic nervous system function. Heart rate variability, a non-invasive marker of parasympathetic activity, diminishes with aging, and in smokers and sedentary people.

Heart Rate variability is affected by both arms of the autonomic nervous system – Sympathetic and Parasympathetic Nervous system. The autonomic nervous system innervates the heart in a number of places. The sympathetic nervous system terminates at the SA node, the conduction system, atrial and ventricular myocardium, and coronary vessels. The parasympathetic fibers terminate in the SA and AV nodes, atrial and ventricular musculature, and coronary vessels. Interplay between the two systems will cause the heart to speed up or slow down, depending on which system is more active. Heart Rate Variability is affected mainly by respiration called the Respiratory Sinus Arrhythmia and blood pressure called the baroreceptor control system. Respiration affects the heart rate through the parasympathetic nervous system. Figure 3.2 illustrates the autonomic innervation of the heart.

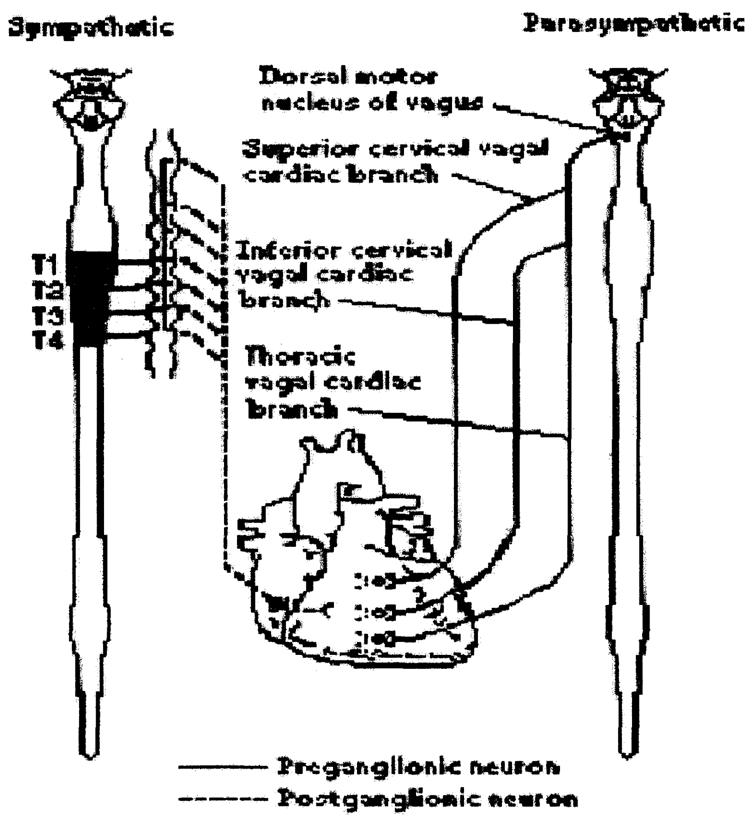


Figure 3.2 Autonomic Innervation of the Heart. (From M.D. Kamath and E.L. Fallen, "Power spectral analysis of heart rate variability," Crit. Rev. in Biomed. Eng., 1993)

Heart rate is principally influenced by two factors: (1) the intrinsic firing rate of the "pacemaker" cells of the sinoatrial node, and (2) the modulating influences of the autonomic nervous system [5]. In turn, the sinoatrial node has dual innervations: (1) the sympathetic system, which enhances spontaneous firing rate, and (2) the parasympathetic system, which exerts a counter inhibitory action, depressing spontaneous firing. The balance between the opposing innervations is the principal determinant of normal heart rate. Heart rate variability (HRV) has been developed as a semi quantitative method of assessing this autonomic activity [15]. "Heart rate variability" has become the conventionally accepted term to "describe variations of both instantaneous heart rate and RR intervals" [15], and is attributed to cyclic fluctuations in autonomic tone.

Focused Breathing

Focused breathing involves sitting quietly while breathing normally at a rate of 12 breaths per minute. The focused breathing session took place at the beginning of the program and 8 and 15 weeks into the program. The focused breathing session is a measure of the heart rate variability of the subject who has undergone the cycles session.

The subjects were instructed to breathe at a regular rate of 12 breaths per minute. This was followed by simultaneous recording of R-R intervals for 5 minutes. Prior to measurement analysis, movement artifacts and ectopic beats were removed. The raw heart rate data was collected, and a power spectral analysis was done using a lab view program. The power spectral analysis is used to compute the powers in the high, low and the very low frequency regions. Since the subjects breathe at a specific rate of 12 breaths per minute, a corresponding activity at 0.2 Hz (high frequency region) is expected.

3.7 Circadian Rhythm

Rhythms are intrinsic to possibly all life forms and occur at all levels of the life form. Circadian rhythms are cycles within a living organism, with a period of 24-hours. The biological role of circadian rhythms of physiological processes consists in adaptation of human body to geophysical and social circadian rhythms, which is synchronized with the life activity processes, maintenance of high activity and resistance to stresses at daytime and restoration of functions at night.

The age and disease related changes are falling of the amplitude of variations outside the limits of normal values, external and internal desynchronization. These abnormalities result in decrease in efficiency of vital activity processes; reductions in mental and physical working abilities, sleep disturbances, and the lessening of body resistance to stresses. The circadian rhythms are physiological functions controlled by the suprachiasmatic nucleus and melatonin, a pineal gland hormone. The suprachiasmatic nucleus rhythmically alters its activity during the day and night sections of 24-hour period, which resembles a sinusoidal wave with a peak and a trough. The changes in illumination intensity over 24-hour period synchronize this rhythm with the geophysical day-night rhythm.

Circadian Rhythm Measurement

The heart rate measuring device – Polar NV HR Monitor is attached to the subject, and the heart rate data is recorded as the subject performs his daily activities. The duration of data measurement is usually 24 hours. The circadian data is collected and is downloaded to the computer. The data is averaged every 5 seconds. Graphs are plotted and the parameters such as ultradian – which is a smaller wave of period one and half hour within the larger 24-hour wave, the peak and the trough of the circadian wave and other parameters of interest are computed. Circadian Rhythm data is used as a key indicator in measuring the progress relative to the cycles program from month to month and year to year.

3.8 Aerobics Measurement

There were eight subjects chosen for this study and they were required to perform their normal exercise regimen. The target heart rate is determined using the same formula (3.1) used in the cycles study. The subjects increase their heart rate as the session increases. In this case the subjects increase their heart rate to a specific value and maintain it followed by a single recovery period.

3.9 Implementation of Cycles Exercise in Insomnia

3.9.1 Introduction

This section discusses the implementation of the cycles exercise protocol in people suffering from insomnia. The study was conducted at the Harvard Medical School and the data collected were heart rate, and physiological measurements like EEG, blood pressure that will be dealt with in detail later in the chapter.

This chapter presents the implementation of the exercise protocol in insomnia subjects, including subject selection criteria, and data acqusition.

3.9.2 Subject Selection Criteria

The data for this study was collected from Harvard Medical School from people suffering from insomnia. The subjects whose ages were above 18 years were eligible unless their history revealed any of the following: smoking, chronic disease, chronic drug or medication use, musculoskeletal limitations or participated in a structured exercise program. All subjects underwent only the cycles program. Physiological data like EEG to monitor the sleep stages were collected to monitor progress after the implementation of the exercise protocol. Each subject was required to sign a consent form, approved by the Harvard Medical School.

3.10 Study Design for Insomnia

The subject population involved in the study was people suffering from Insomnia. The objective was to see if performing cycles lessened the effects of the disease, in other words helped the individuals to sleep. The subjects underwent a cycles baseline test and their target heart rates were determined. There were no focused breathing or circadian sessions prior or at the completion of program as a measure of progress. The study duration was seven weeks, three-cycle session per week, making 21 sessions in all. The physiological test that monitored the sleep stages of the subjects conducted in the end revealed e considerable improvement in the EEG values. The subjects were required to fill a questionnaire to assess the subjective sense of well-being.

3.11 Protocol Implementation

Insomnia, as classified as a sleep disorders, is associated with complaints about the quantity, quality or timing of sleep at least three times a week for at least one month. Insomnia has been classified in at least three different ways by comorbidity, duration and severity. Subtypes of extrinsic and intrinsic classifications for insomnia include inadequate sleeping habit, insufficient sleep, altitude insomnia and environmental insomnia. Comorbidity is the presence of coexisting or additional diseases with reference to an initial diagnosis or with reference to the index condition that is the subject of study. Comorbidity may affect the ability of affected individuals to function and also their survival; it may be used as a prognostic indicator for length of hospital stay, cost factors, and outcome or survival. Common recommendations include: regular daytime exercise; avoiding large meals at night; avoiding caffeine, tobacco and alcohol; reducing evening fluid intake; limiting the use of the bedroom to sleep; maintaining a consistent wake-up time; avoiding or limiting daytime napping and avoiding bright lights (including television), noise and temperature extremes. [19] Early exercise is the best way to reset the body's rhythm. The body temperature generally rises during the day and begins to decrease as bedtime approaches. By exercising early, the body will train itself to heat up and cool down faster. [20]

The participants underwent a baseline evaluation prior to the 7-week exercise regimen, which was also used to determine each subject's exercise prescription. The cycles protocol is designed to create a series of parabolic waves of cardiovascular exercise and recovery. A single cycle consisted of short burst of exercise, which is usually less than a minute followed by cardiovascular recovery. The exercise phase of the cycles consisted of jogging on the trampoline at an easy pace (3 on a 10 point Borg scale) until the heart rate stabilized. This usually occurred within one minute of exertion. In the insomnia study the files were 5 second averaged heart rates monitored by a trainer and recorded continuously by using a Polar NV HR Monitor watch and chest strap (Polar Electro Inc., Woodbury NY) and then downloaded to a computer. The subject then stopped the exercise and took a deep breath and pushed a button indicating the deep breath timing and began initiating the recovery phase of the cycle including the relaxation response. When the subject recovered, again defined as stable heart rate, the subject again took a deep breath once again indicated by a button push. The subjects performed the 2nd, 3rd, 4th and the 5th cycle but with increased exertion. The fifth cycle was used to determine the peak heart rate for the subsequent sessions and consisted of vigorous, brief exertion (9 on a 10 point Borg Scale) and continued till the subject completed one minute of exertion. The subject then began the final recovery phase of the cycles session. Once the cycles baseline testing was completed, the subject began the actual cycles session lasting for seven weeks monitored by a trainer. Target heart rates were calculated as percentages of peak heart rates determined from the fifth cycle of the baseline session and are determined for all 21 sessions. Table 3.2 shows the target heart rates and the exertion level of a specific session of a subject. [10]

Table 3.2 Target Heart Rates for Insomnia study of Subject E04

TargetHeart Rates in Beats/min	**Exertion Level**
118	1
129	2
149	3
158	4
146	5

1) Exertion Scale:
2) Easy Pace
3) Accelerate to Moderate Pace
4) Accelerate to Moderately Vigorous Pace
5) Accelerate to Vigorous Pace (Maximum Effort}
6) Maximum effort from the start of the cycle to the finish (Spike)

The target heart rates for 21 sessions are determined from the baseline session. The subject undergoes 5 cycles per session. Table 3.3 shows the button push timings and the cycle of a particular subject. The button that is pushed on the polar NV heart rate monitor indicates the occurrence of a deep breath.

Table 3.3 Cycle Numbers and the Button Push Timings of Subject E04

Cycle Number	**Button Push–Beginning of Recovery phase in minutes and seconds**	**Button Push – End of Recovery Phase in minutes and seconds**
1	0:00:57.8	0:01:59.9
2	0:05:00.6	0:06:00.0
3	0:09:01.3	0:10:00.1
4	0:15:00.4	0:16:00.5
5	0:22:01.0	0:23:00.8

The above table shows the push button timings and the corresponding cycle numbers. The button push is for the calculation of the deep breath magnitudes. The button is pushed at the beginning of the recovery period and at the end of the period where the subject takes a deep breath. Deep breath parameter is direct indicator of heart rate variability.

3.12 Psychological Measurements

The Mental Health Inventory Index is used to measure changes in psychological status. The quality of life of the subjects was measured after the completion of the study in both the study groups. In addition, physiological tests like measurement of blood pressure in both study groups, monitoring of sleep stages by recording EEG data, tests to measure the immune system of the subjects in the AIDS study were also conducted.

CHAPTER 4

DATA ACQUSITION AND ANALYSIS

4.1 Introduction

The data acquired during the implementation of the protocol included the heart rate during exercise, focused breathing and circadian rhythm for the AIDS study at the Philadelphia FIGHT Institute, and only the exercise data for the insomnia study at the Harvard Medical School.

The tools used for analysis were Mathematica and LabView. This section describes the use of both Lab View and Mathematica in this project and the algorithms by which the different physiological signals are analyzed.

4.2 Cycles Data Acqusition for the AIDS Study

The heart rate exercise data acquired for the AIDS study, involved the recording of R-R intervals or, the interbeat interval in milliseconds. The equipment used during data collection was a, simple to use heart rate measurement device - the Polar NV HR Monitor, including the chest strap. For registration of R-R intervals using the Polar® system an elastic belt (Polar T31™ transmitter, Polar Electro, Kempele, is fixed to the chest of the volunteer at the level of the lower third of the sternum. The belt contains a case with heart rate electrodes, electronic processing unit and electromagnetic field transmitter. The heart rate signals are continuously transmitted to the receiver unit via an electromagnetic field. The required distance between transmitter and receiver for successful signal registration is 10-90cm. The receiver is connected to a computer through a serial port. The digitally coded R-R interval length is continuously submitted to the software Polar® Precision Performance® that in turn displays a heart tachogram on the monitor [18]. The subject then performed the cycles exercise with an increased target at every successive cycle. The cardiovascular parameters that were calculated during the implementation of protocol were

- Mean Heart Rate
- Range of duration of R-R intervals.

Cycles Analysis

After the completion of the baseline test the subjects started with the actual cycles session. Target heart rates were calculated as percentages of peak heart rate determined from the baseline session. The target heart rates began at the low end of the cycle and progressively increased in an incremental fashion. During the cycles that required high heart rates, the subjects exercised on trampolines with hand weights to assist in reaching such high heart rates within the allotted 60 seconds. A trainer tracked the participants as they moved through the same type of exercise-recovery cycles. [10]

The heart rate data collected during exercise is in the form of interbeat interval in milliseconds. The data is then converted into beats/min using the formula:

$$\text{Heart rate in Beats/Minute} = 60{,}000\text{milliseconds/min} \,/\, \text{data point in milliseconds/beat} \quad (4.1)$$

and the other parameters are analyzed using a Mathematica program (Version 4.1). The Mathematica code is shown in the appendix. Figure 4.1 shows the graph of the cycles data. The parameters that are extracted from the exercise data are as follows:

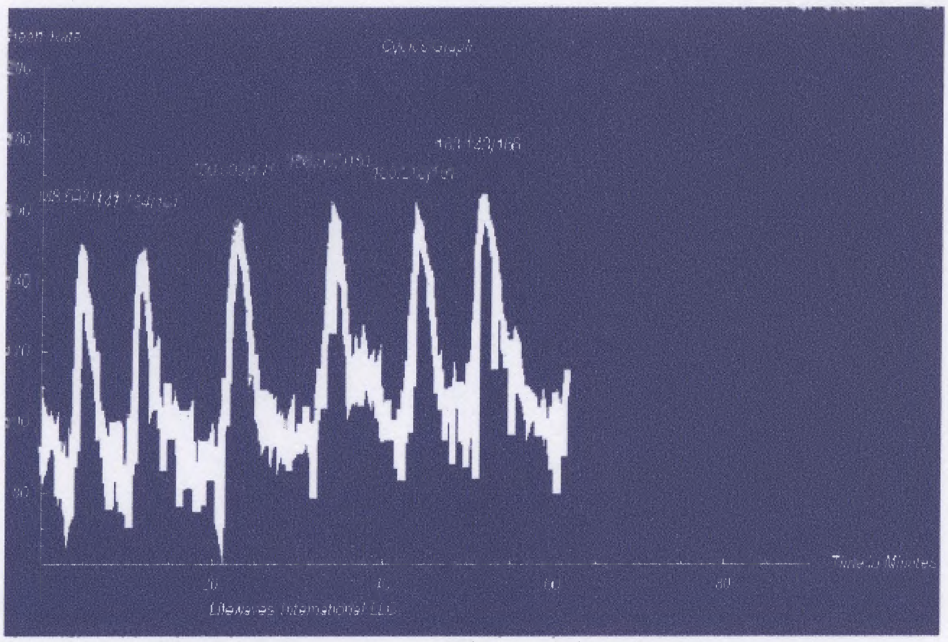


Figure 4.1 Graph of the cycles and the peak heart rates.

Deep Breath Average (Dbav): During the cycles session, the subject takes a deep breath, indicating it by means of a button push. This button that is located on the polar NV heart rate monitor, inserts a marker in the file indicating the time of occurrence of deep breath. Deep breath magnitude enhances the heart 3.3 displays the cycle numbers and button push timings for a particular subject. Table 4.1 displays the magnitude of the deep breath values of a specific subject – C10 during the baseline, week 7 and week 12 respectively.

Table 4.1 Magnitudes of Deep Breath Values of Subject C10

Weeks	**Deep breath Magnitudes**
Baseline	14.31
Week7	18.42
Week12	20.88

From the above table it is seen that there is an increase in the magnitude of the deep breath value from the baseline value to the completion of the program. This increase magnitude is an indicator of augmentation of parasympathetic activity and hence the heart rate variability. This deep breath also helps the parasympathetic nervous system during the cycles recovery.

Pos Peak: This is a two dimensional parameter and consists of the position and the timing of the occurrence of the peaks of the cycles. It shows the highest heart rate achieved by a subject during the execution of the cycle. Table 4.2 illustrates the pos peak parameter of the subject C15 during a specific session.

Table 4.2 Cycle Numbers, Peak Position and Peak Values of Subject C15

Cycle Number	**Pos Peak– Position**	**Pos Peak – Peak Value Achieved / Set in beats/min**
1	157	134.532/131 (2)
2	273	146.068/141(3)
3	420	159.319/147(4)
4	595	152.364/151(5)
5	760	167.992/No Goal
6	920	150.908/141(5)

The above table shows the pos peak parameter consisting of the position of the peak in the data file and the highest value of heart rate achieved by the subject C15 against the target heart rate determined from the baselines session.

Pos Min: This is also a two dimensional parameter, which indicates the minimum of the cycles and its position. Table 4.3 shows the cycle numbers and the cycle minimum and its position achieved by each subject.

Table 4.3 Cycle Numbers, Cycle Minimum and Position of Subject C15

Cycle Number	Pos min – Position	Pos min – Minimum Value in beats/min
1	95	74.8483
2	223	72.8506
3	363	81.4053
4	515	85.822
5	717	90.6422
6	849	93.9691

The table above shows the minimum value attained by each cycle after recovery. The posmin position indicates the position of the minimum value of the cycle in the data file.

Base: Base represents the initial relaxation phase of the subject before the actual cycles session. Base is the average of the first fifty data points, where the subject relaxes and takes a deep breath, before actually performing the cycles.

$$\text{Base} = \text{Average of first fifty data points} \tag{4.2}$$

Post Base: Post Base represents the final relaxation phase of the subject after the cycles session and is the final 3 minutes of data starting 2 minutes after the final peak.

$$\text{Post Base} = \text{Average of 36 data points starting 2 minutes after the final peak} \tag{4.3}$$

Slope Base: is an important measure of progress during the cycles session. Slope Base parameter is the increase in heart rate baseline from prior to the cycles program to its completion. The slope base parameter is calculated using the formula

$$\text{Slope base} = \text{Post Base} - \text{Base} / \text{Postbasepos} - \text{Prebasepos} \tag{4.4}$$

Post base pos is the position, which occurs 2 minutes after the final peak and pre base pos is the position, which occurs 1 minute before the first peak. Table 4.4 shows the slope base values during the baseline, week 7 and week 12 respectively for subject C10.

Table 4.4 Slope base values of Subject C15

Time of the cycles session	**Initial value of the slope base**	**Final value of the slope base**
Morning	0.1408342	0.287675
Afternoon	0.0667771	0.1130362

The above table shows the slope base values of the morning and afternoon sessions. The data in table 2 shows an example of the slope base values for subject C15 taken at the beginning and at the end of the study. Since the cycles performed at different times of the day might result in different values of slope base, data is included for both morning and afternoon cycles. The table above indicates that there is an increase in the slope base values from the initial session to the final sessions. This increase denotes an increase in the value of ultradian and hence the magnitude of the circadian rhythm.

Upslope and Downslope: Upslope and Downslope represents the acceleration and recovery phase of the cycles. Table 4.5 shows the upslope and the downslope values for baseline, week 7 and week 12 respectively for the subject C10. The upslope is the maximum of slope of the acceleration curve and downslope is the maximum slope of the recovery part of the curve.

Table 4.5 Upslope and downslope values for Subject C10

Weeks	Upslope	Downslope
Baseline	1.55474	2.19854
Week 7	2.31377	1.60646
Week 12	2.66486	2.61907

From the above table it is seen that there is an increase in the upslope and downslope values from the baseline to the final session. An increase in the upslope values indicates that the subject is able to achieve the target heart rate faster. An increase in the downslope values indicates that the subject is able to recover faster after the cycles session, which improves body's natural response to stress.

Total, Left and Right Error: A parabola fit into the cycles and its variation from the actual parabolic dimensions is listed as the total, left and the right error.

There are two measures of these parabolic errors.

The total error gives the overall error when a cycle is fit into the actual parabola. The better the fit, healthier a person.

The left and the right errors give the symmetrical variation of the acceleration and the recovery slope of the parabola. Table 4.6 illustrates the following

Table 4.6 Total, Left and the Right Errors of Subject C10

CycleNumber	TotalError	LeftError	RightError
1	52.1706	36.3792	20.6431
2	21.9712	8.31954	15.6595
3	56.1295	15.3163	44.2271
4	49.5111	15.722	36.9559
5	8.71162	4.51406	4.56161
6	51.4854	1.6415	50.2711

Max cycle: This indicates the maximum peak of the cycle attained during each cycles session.

No Goal: Do a spike (maximum effort from the start of the cycle to the finish), but stop if your heart rate stops rising, if your heart rate drops, if you become tired, or if you have gone for a full minute. The no goal is an estimate of the maximum heart rate of the subject during exercise without any restrictions.

4.3 Data Acqusition and Analysis - Focused Breathing

During focused breathing data acqusition the subject was required to sit comfortably and relax. The subjects were required to sit quietly and breathe at a specific rate of 12 breaths per minute for 5 minutes. The reason for choosing 12 breaths is that it is an average breathing rate and the predominant frequency of respiration is at 0.2 Hz. (12 breaths per minute). The data was analyzed using the Lab View (Version 5.1). If the file did not last for 5 minutes, the high frequency power and the low frequency power, computed during the focused breathing session were normalized using the formula

Normalized HF or LF area = HF or LF area * 5/ original length of the file (4.5)

To observe variability in consecutive cardiac cycles, a continuous ECG signal may be used. The R wave serves as a marker of each beat position and because of its distinctive shape and prominent amplitude, it becomes the easiest part of the beat for computer detection [8]. The basic measurement is the time interval between heart beats as calculated from consecutive R waves obtained in the ECG (Figure 4.2). The construction of this interbeat interval (IBI) involves several steps. Each R wave is detected and a pulse is produced at the position of each R wave. The height of each pulse is adjusted to be the length of the previous RR interval. For example, two successive pulses occur at T_1 and T_2 seconds, respectively, where the distance between the two is Y. Therefore, the interval of Y seconds becomes the height of the pulse that occurs at time T_2. The consecutive pulses that follow form a pulse wave. This pulse wave is interpolated to produce a wave with equally spaced samples. This type of interpolation is called backward step interpolation where the height of the wave in a time interval is kept constant at the value of the length of the time interval. This IBI signal will become the basis from which information on HRV will be obtained.

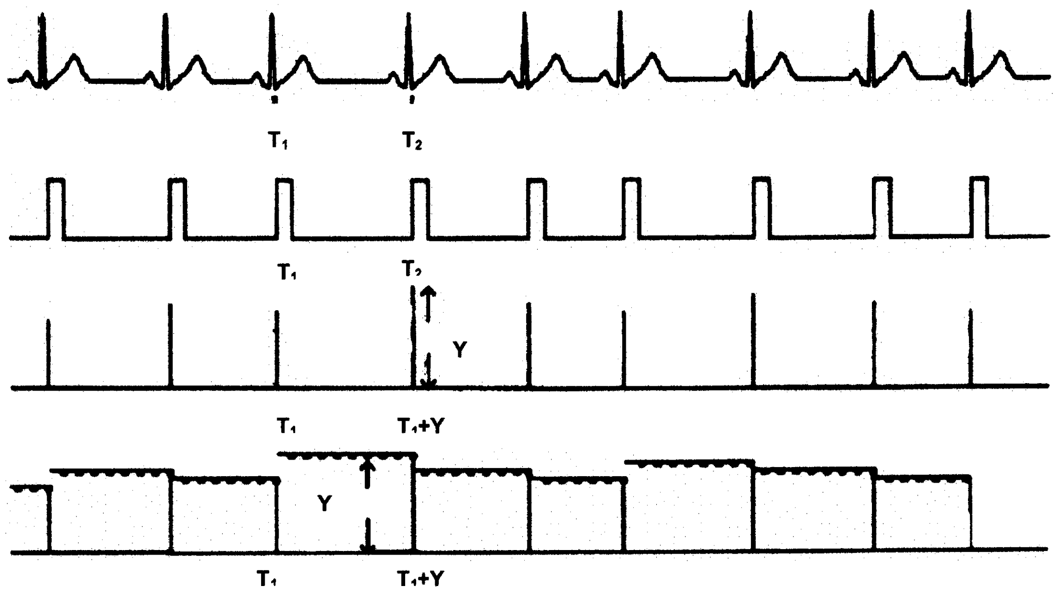


Figure 4.2 Steps in the construction of an interbeat interval (IBI) signal. (From S. Shin, W. N. Tapp, S. Reisman, and B. H. Natelson, "Assessment of Autonomic Regulation by the Method of Complex Demodulation," IEEE Transactions in Biomedical Engineering, vol. 36, pp. 274-283, 1983.)

Three major frequency bands can be distinguished in the power spectrum of the interpolated IBI signal called the IIBI, where each is generally associated with different systems that control heart rate and calculated from short-term recording of approximately 5 minutes (Figure 4.2).

The three frequency bands are as follows:

High Frequency Region: The area under the spectrum between frequencies 0.15Hz and 0.4Hz is the high frequency region and is an indicator of parasympathetic activity. The major activity in this band is due to respiration and a predominant peak usually occurs at the respiration frequency.

Low Frequency Region: The area under the IIBI spectrum in the frequency band between 0.05Hz and 0.15Hz is the low frequency band and is influenced by both the parasympathetic and sympathetic nervous systems and largely due to the variability in the blood pressure control system.

Very Low Frequency Region: The band of frequencies between 0.02Hz and 0.05Hz is called the very low frequency band and is mainly due to the activity of the temperature control system. [21]

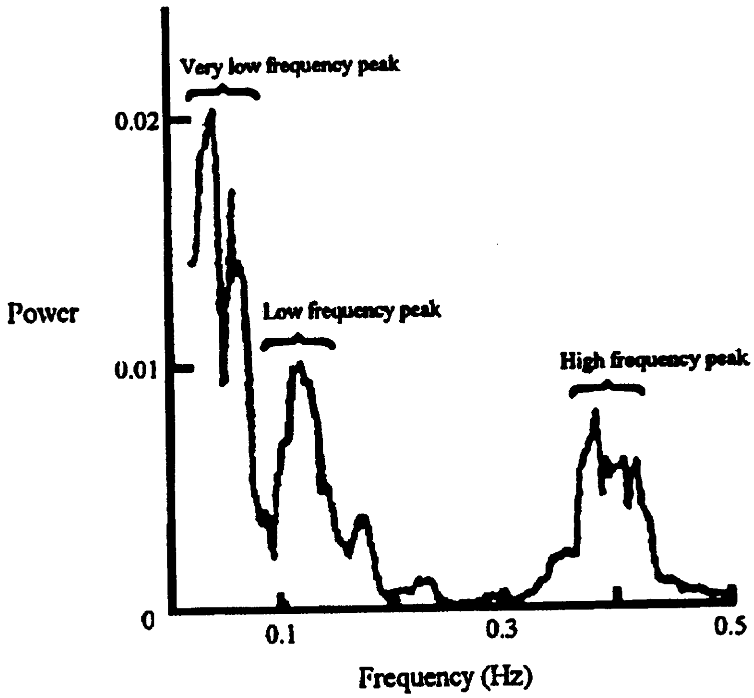


Figure 4.3 Frequency spectrum of an interbeat interval signal. (From M. V. Kamath and E. L. Fallen, "Power Spectral Analysis of Heart Rate Variability: A Noninvasive Signature of Cardiac Autonomic Function." Clinical Reviews in Biomedical Engineering, vol. 21, pp. 245-311, 1993.)

Figure 4.4 shows the raw heart rate data taken during focused breathing and the heart rate power spectrum. The information obtained from the heart rate power spectrum is analyzed. The predominant frequency of respiration is at about 0.2 Hz (12 breaths per minute) and that the predominant peak in the high frequency region occurs at the respiration frequency. There is little activity in the low frequency region indicating the high parasympathetic activity in this region.

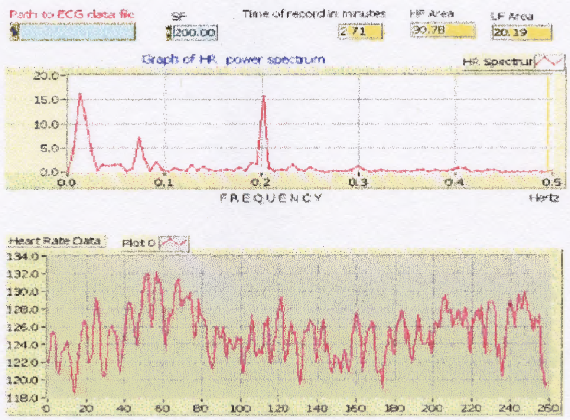


Figure 4.4 Graph of the raw heart rate data and the heart rate power spectrum.

4.4 Data Acqusition and Analysis – Circadian Rhythm

The shape of the 24-hour circadian rhythm is another significant indicator of overall health. The shape of the circadian rhythm reflects all the daily activities and behaviors. One important aspect to watch for in the circadian rhythm is the time of the peak and the time of the trough. In a normal person, the peak should be in the afternoon, around 4:00pm, and the trough, in the early morning, around 4:00 a.m. This circadian wave is built from another set of waves that occur every one and half-hours called the ultradians whose magnitude is an important criterion for evaluation of healthy or diseased subjects. A typical Circadian rhythm file is shown in Figure 4.5.

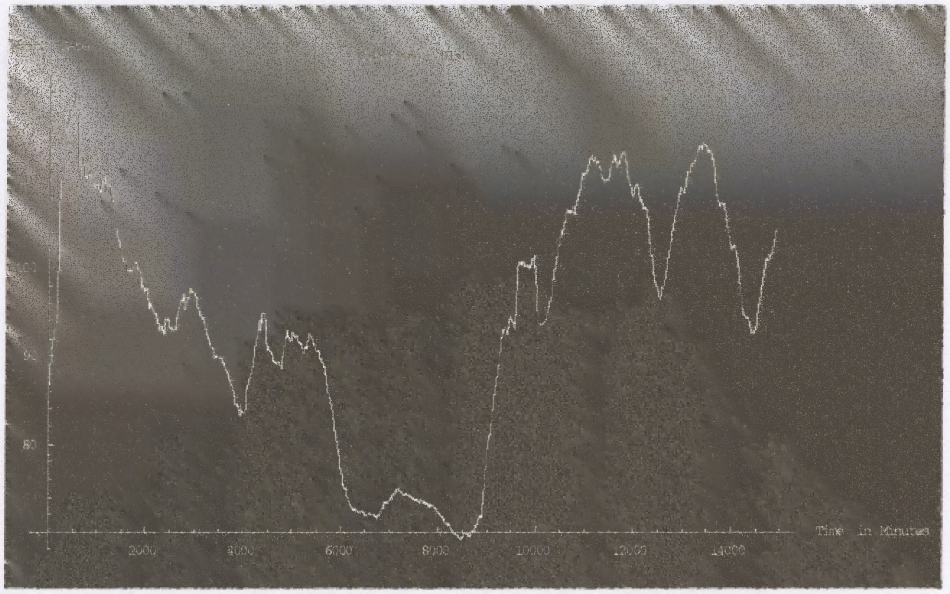


Figure 4.5 A circadian file showing the peak and the trough.

The data is recorded when the subject performs his daily activities. The file duration is for 24 hours and the data that is obtained is the heart rate in beats per minute which is averaged every 5 seconds.

The important parameters are

Circ max: This parameter denotes the position of the peak in the file of the 24-hour cycle.

Circ min: This parameter denotes the position of the minimum in the data file of the 24-hour cycle.

Table 4.7 Circmax and the Circmin Values of Subject C10

Weeks	**Circmax**	**Circmin**
C10week8assesment 24 hour	567	8449
C1024hour5202 week 16	3887	581

The above table represents the position of the occurrence of a peak and trough in the data file, in other words the position of the heart rate values during the occurrence of the peak and trough respectively

Circpd: The represents the time between the peak and the trough of the circadian file and should typically be 12 hours.

Vcircmax and Vcircmin: represents the amplitude of the peak and trough during the the24-hour cycle

Vx1 and Vn1: The circadian rhythm is made of smaller waves of one and half hour duration called the ultradian waves. The parameters Vx1 and Vn1 represent the maximum and the minimum values of the ultradians.

4. 5 Data Acqusition - Aerobics

The subject wears the heart rate NV monitor and performs the exercise regimen. The data is then downloaded to the computer and analyzed. As the aerobics session progresses, one can see an increase in the target heart rate. The graph showing a typical aerobics regimen is shown below.

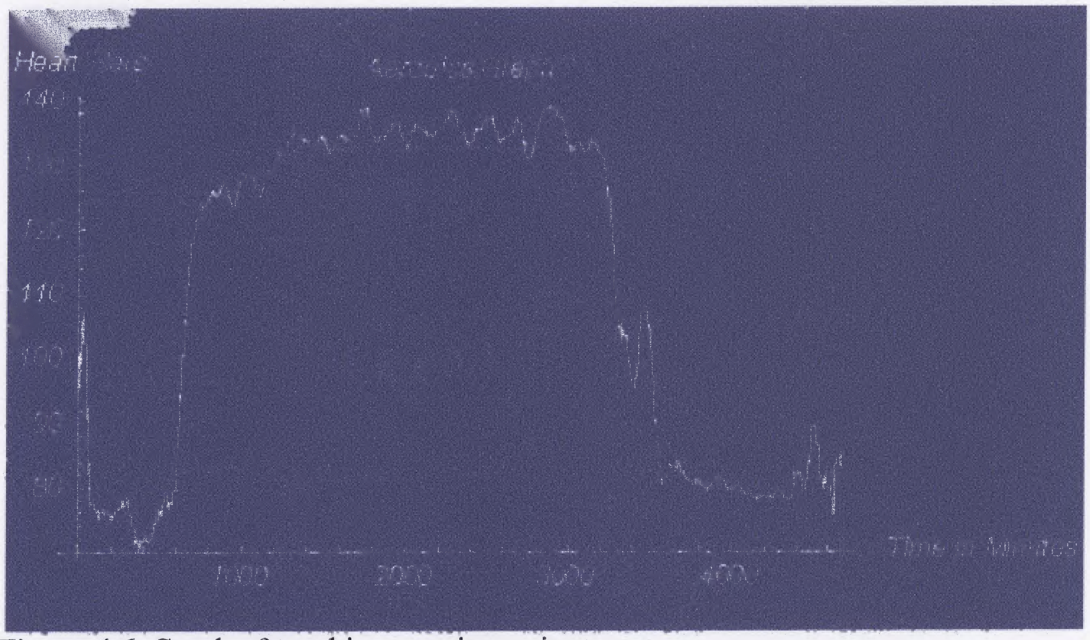


Figure 4.6 Graph of aerobics exercise regimen.

4.6 Data Acqusition and Analysis – Insomnia Study

This section deals with data acqusition and analysis during the implementation of the cycles protocol on people suffering from insomnia. The data acqusition is the same as in the AIDS study, except that the heart rate data are collected in beats per minute and are averaged every 5 seconds, also no focused breathing or circadian data is acquired.

The parameters extracted from the heart rate data using Mathematica program is the same as for the AIDS study. During the implementation of the protocol, the subjects did not have at longer relaxation period after the completion of the cycles session. Therefore, the slope base parameter had to be redefined discussed in detail in the chapter and then analyzed.

Deep Breath Average (Dbav): This parameter shows the average of the magnitudes of all the deep breath values, taken during the beginning and at the end of the recovery phase.

Table 4.8 Sessions and the Deep Breath Magnitudes of Subject E04

File name	Deepbreath Magnitudes
02-11-04 e04	7
02-11-06 e04	8
02-11-11 e04	9

From the above table it can be seen that there is an increase in the deep breath magnitudes. Deep breath value is a direct indicator of heart rate variability and it also enhances training recovery.

Pos Peak and Pos Min: This shows the target heart rates, the cycle minimum and the positions achieved by each subject during a cycle session. The table below shows the pos peak and the minimum values of a subject.

Table 4.9 Pos peak and the Pos Min Values of Subject E04

Cycle number	PosPeak-Position	Pos Peak-Peak Achieved/Set	PosMin Position	PosMin Minimum
1	81	105/116(2)	6	57.8095
2	132	116/127(3)	91	58.7619
3	182	141/141(4)	141	59.6667
4	228	143/128(4)	148	61.2857
5	288	144/131(5)	237	62.9524

The above table shows the cycle peak values achieved by the subject against the target heart rate values determined from the baseline session. The minimum values of the cycles and their position in the data file are also given.

Base: This represents the initial relaxation phase of the subject before the actual cycles session.

Post Base: This represents the recovery time of the next to last cycle and is an average of eight data points starting one minute after the next to last peak. This is due to the fact that the subjects did not rest for long after the completion of the cycles session.

Slope Base: This is the rise in the baseline of the heart rate signal and is a measure of progress. The slope base is defined using the formula

$$\text{Slope base} = \text{Post Base} - \text{Base} / \text{Postbasepos} - \text{Prebasepos} \quad (4.6)$$

Post base position is the position, which occurs one minute after the fourth peak and Pre base position is the position, which occurs one, minute before the first peak.

Upslope and Downslope: Upslope and Downslope represents the acceleration and recovery phase of the cycles.

Total, Left and Right Error: A parabola fit into the cycles and its variation from the actual parabolic dimensions is listed as the total, left and the right error.

Max cycle: Represents the highest peak achieved by the subject during a cycles session, which is ideally the final and the fifth cycle.

No Goal: Do a spike (maximum effort from the start of the cycle to the finish), but stop if your heart rate stops rising, if your heart rate drops, if you become tired, or if you have gone for a full minute. Figure 4.7 illustrates the cycles graph performed by a subject during the Insomnia study.

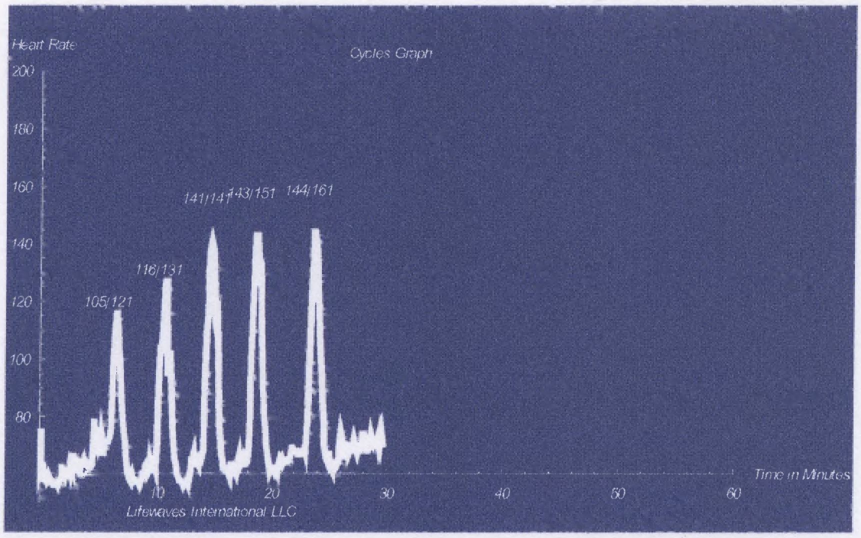


Figure 4.7 Cycles performed Subject E11 during the insomnia study.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Introduction

This chapter discusses the results obtained in this study for both the AIDS and Insomnia subjects. The data is statistically plotted and analyzed using paired t-test for means. A linear trendline is fitted on the plots and the slope is calculated in every parameter.

The plots and their paired t-test results including the slope for each parameter are discussed in this section. A paired t-test is performed to compare two sets of data in the same database. The coincidence and variation of results in the two studies are seen.

5.2 Results from the AIDS Study

Deep Breath Variable: The increase in deep breath magnitudes during the progress of the cycles session is observed in the data. The deep breath values were calculated manually, magnitudes of baseline, weeks 8, 16 (If the subject underwent the cycles session for 16 weeks) otherwise the deep breath magnitude obtained at the final cycles session is obtained. Table 5.1 showing the results for the deep breath magnitudes for baseline, week 8 and at the end of the session for a specific subject.

Discussion: There was a small but significant increase in deep breath value. This is of considerable importance because; the deep breath enhances the training recovery, which in turn enhances parasympathetic activity and hence heart rate variability. Deep breath is a direct indicator of heart rate variability.

Table 5.1 Weeks and Deep Breath Magnitudes for Subject C10

Weeks	**Deep breath Magnitudes**
C15baseline	5.16
C15 week7session3	7.86
C15week15session3	17.09

Slope base: This variable denotes the rise in the baseline of the heart rate signal from the prior to the completion of the session. This is an important measure of progress. The graph 5.1 shows the increase the slope base parameter for a specific subject. Table 5.2 shows the slope base values for a specific subject.

Table 5.2 Slope Base Sessions and Values for Subject C10

SubjectC10	**Session I**	**Time**	**SessionII**	**Time**	**SessionIII**	**Time**
Week 1	0.034	8:15:08AM	0.050	8:02:27AM	0.055	8:00:35AM
Week 2	0.031	9:18:09AM	0.012	9:29:58AM	0.051	8:59:09AM
Week 3	0.031	3:35:04PM	0.035	3:01:57PM	0.046	3:07:46PM
Week 4	0.020	8:13:41AM				
Week 5	0.009	9:18:16AM				
Week 6	0.029	3:30:15PM	0.059	3:03:16PM	0.028	3:06:12PM
Week 7	0.053	8:26:30AM	0.079	8:21:51AM	0.071	8:10:27AM
Week 8						
Week 9						
Week 10						
Week 11	0.027	7:11:22AM	-0.472	7:05:56AM	0.154	7:48:37AM
Week 12	0.053	2:48:54PM	0.037	3:04:40PM		

The blank spaces indicate that the subject was not present for the particular session.

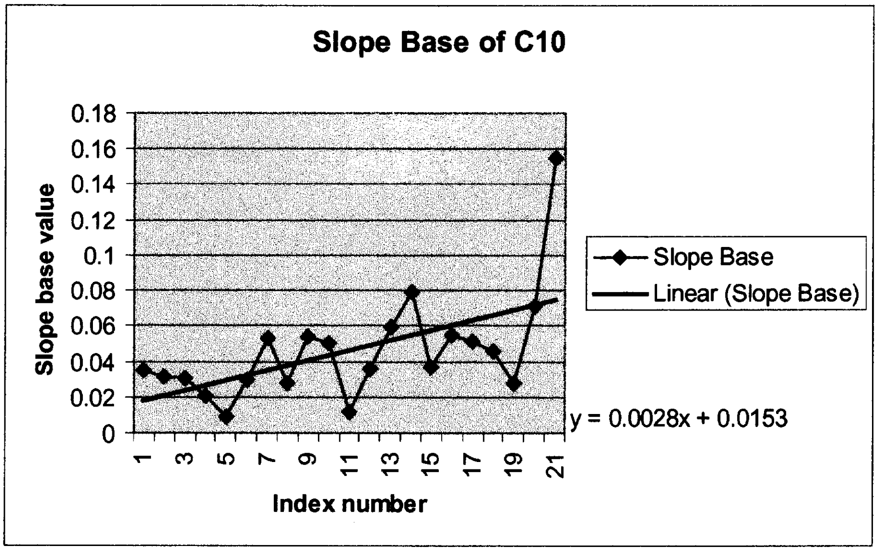


Figure 5.1 Graph showing the increase in the slope base of subject c10

From the graph one can see that there is an increase in the slope base parameter. A trend line is fitted on the curve and hence the slope equation displayed and calculated. Also seen from the graph, there is a positive slope indicating an increase. This is not true in all the subjects. Results have shown that there were negative slope for certain subjects. Figure 5.2 shows the graph of a subject that did not show an increase in slope base value.

Discussion: The reason why the slope base parameter is of utmost importance is because; an increase in magnitude of the slope base value indicates an increase in the magnitude of the ultradian rhythm. Ultradians are waves of 1.5-hour duration that make up the larger wave – the circadian rhythm. In other words, the increase in the magnitude of the slope base value is projected on the circadian rhythm as an increase in the magnitude of the ultradian rhythm. An increase in the slope base parameter is statistically analyzed by means of t-test paired two sample for means and is shown below and the P (T<=t) one tail was observed to be $p = 0.05$. Statistical significance is defined as $p<0.05$.

Table 5.3 Data Values for Slope Base Analysis of Subject C10

InitialValues	Times	FinalValues	Times
0.034	8:15:08AM	0.053	8:26:30AM
0.050	8:02:27AM	0.079	8:21:51AM
0.055	8:00:35AM	0.154	7:48:37AM
0.031	3:35:04PM	0.053	2:48:54 PM
0.035	3:01:57PM	0.037	3:04:40 PM

Since the time of the day exerts a considerable influence on the cycles session, the initial and the final slope base values were selected based on the morning or afternoon sessions.

t- test for the above data is shown below

Subject C10	Variable 1	Variable 2
Mean	0.041522	0.07577
Variance	0.000115	0.002173
Observations	5	5
Pearson Correlation	0.860786	
HypothesizedMeanDifference	0	
Df	4	
T Stat	-2.02773	
P (T<=t) one-tail	0.050251	
T Critical one-tail	2.131846	
P (T<=t) two-tail	0.112503	
T Critical two-tail	2.776451	

A t-test statistical analysis conducted on the slope base values of all the subjects between the initial and the final week did not reveal a significant increase in the values. The statistical significance was $p = 0.11 > 0.05$. The table below shows the initial and final values considered for analysis for all subjects and its statistical significance.

Table 5.4 Initial and Final Values of Slope Base for All Subjects

Subject	Initial Values	Final Value
C05	0.052	0.065
C08	0.041	0.063
C10	0.034	0.154
C15	0.062	0.123
C22	0.033	0.063
C25	0.037	0.137
C37	0.074	0.133
C53	0.073	0.444

The t- test values are shown in the table below.

Subject C25	Variable 1	Variable 2
Mean	0.0514502	0.148435688
Variance	0.000291854	0.01567693
Observations	8	8
Pearson Correlation	0.554584927	
HypothesizedMeanDifference	0	
Df	7	
T Stat	2.352567553	
P (T<=t) one tail	0.025447412	
T Critical one-tail	1.894577508	
P (T<=t) two-tail	0.050894824	
T Critical two tail	2.36462256	

From the above Table 5.4 and its corresponding t-tests, it is evident that there is no significant increase (p=0.0508 = 0.05) values for all subjects from the beginning to the end of the session. The graph below shows the subject's slope base parameter that did not increase throughout the cycles session. This subject's cycles session did not last for 12-16 weeks. This is one of the limitations of the study. Limitations are discussed in the next chapter.

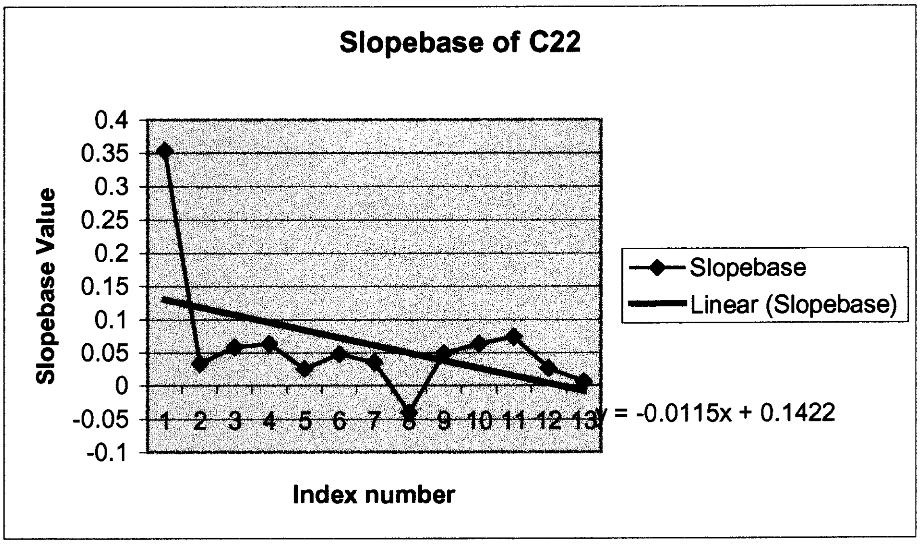


Figure 5.2 Subject C22 showing a decrease of slope base value.

Upslope Value: Upslope indicates the acceleration of the cycles or the exertion phase. This is also another important parameter of progress in the cycles session. A graph showing an increase in the upslope parameter as the cycles session progresses.

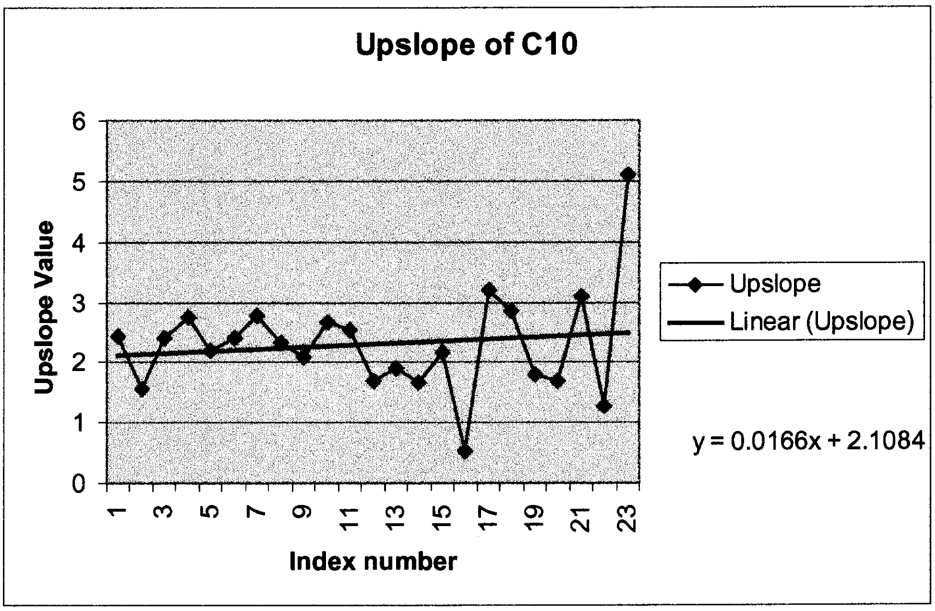


Figure 5.3 Increase in the upslope parameter of a subject C10.

A trend line is fitted on the graph and hence the slope is calculated and displayed. A positive slope indicates an increase in the parameter.

Table 5.5 Values and Times of the Upslope Parameters for Subject C10

SubjectC10	**Session1**	**Time SI**	**Session2**	**Time SII**	**Session3**	**Time SIII**
Baseline	2.437	9:56:52AM				
Week1	1.554	8:15:08AM	2.537	8:02:27AM	2.864	8:00:35AM
Week 2	2.402	9:18:09AM	1.689	9:29:58AM	1.805	8:59:09AM
Week 3	2.737	3:35:04PM	1.895	3:01:57PM	1.688	3:07:46PM
Week 4	2.201	8:13:41AM				
Week 5	2.411	9:18:16AM				
Week 6	2.763	3:30:15PM	1.665	3:03:16PM	3.084	3:06:12PM
Week 7	2.313	8:26:30AM	2.170	8:21:51AM	1.280	8:10:27AM
Week 8						
Week 9						
Week 10						
Week 11	2.083	7:11:22AM	0.5309	7:05:56AM	5.088	7:48:37AM
Week 12	2.664	2:48:54PM	3.200	3:04:40PM		

The blank spaces denote that the subject did not perform that cycle session.

Discussion: An increased Upslope value indicates that the subject is able to achieve the target heart rate value faster. This has a positive physiological influence on the heart and it reflects on the heart's ability to respond to stress faster. A t-test done for a single subject showed an increase in the upslope values as seen from the Table 5.7.

A t-test done to test the statistical significance of the slope base value for all the subjects did not reveal an increase in the parameter $p = 0.0626 > 0.05$

Table 5.6 Initial and Final Upslope Values for All Subjects

Subject	Initial Values	Final Value
C05	0.052	0.065
C08	2.362	2.700
C10	1.554	5.088
C15	1.614	2.032
C22	1.749	2.571
C25	1.678	3.299
C37	2.602	2.455
C53	1.210	2.047

t-test values for the upslope values for all subjects are as follows

All Subjects	Variable 1	Variable 2
Mean	1.60318755	2.5327267
Variance	0.594647083	1.961417511
Observations	8	8
Pearson Correlation	0.529072098	
HypothesizedMeanDifference	0	
Df	7	
T Stat	-2.211549229	
P (T<=t) one-tail	0.031326908	
T Critical one-tail	1.894577508	
P (T<=t) two-tail	0.062653817	
T Critical two-tail	2.36462256	

From the above t-test, there is no significant increase in the upslope values and is evident from the fact that the value of p= 0.06>0.05.

Table 5.7 Initial and Final Upslope Parameters for Subject C10

Initial Value	Times	Final Value	Times
1.554	8:15:08 AM	2.083	7:11:22 AM
2.864	8:00:35 AM	5.088	7:48:37 AM
1.895	3:01:57 PM	2.664	2:48:54 PM
1.688	3:07:46 PM	3.200	3:04:40 PM

The t-test values are shown below

Subject C10	**Variable 1**	**Variable 2**
Mean	2.00095	3.259423
Variance	0.351412	1.695694
Observations	4	4
Pearson Correlation	0.944119	
HypothesizedMeanDifference	0	
Df	3	
T Stat	-3.27816	
P (T<=t) one-tail	0.023245	
T Critical one-tail	2.353363	
P (T<=t) two-tail	0.04649	
T Critical two-tail	3.182449	

As seen from the above table the value of P-two tail (t<=T) is 0.04, which is less than 0.05. Statistical significance is defined as $p<0.05$.

Downslope Value: Downslope indicates the recovery slope of the cycles. The graph shows an increase in the downslope values. A trend line is fitted on the graph and hence the slope is calculated and displayed.

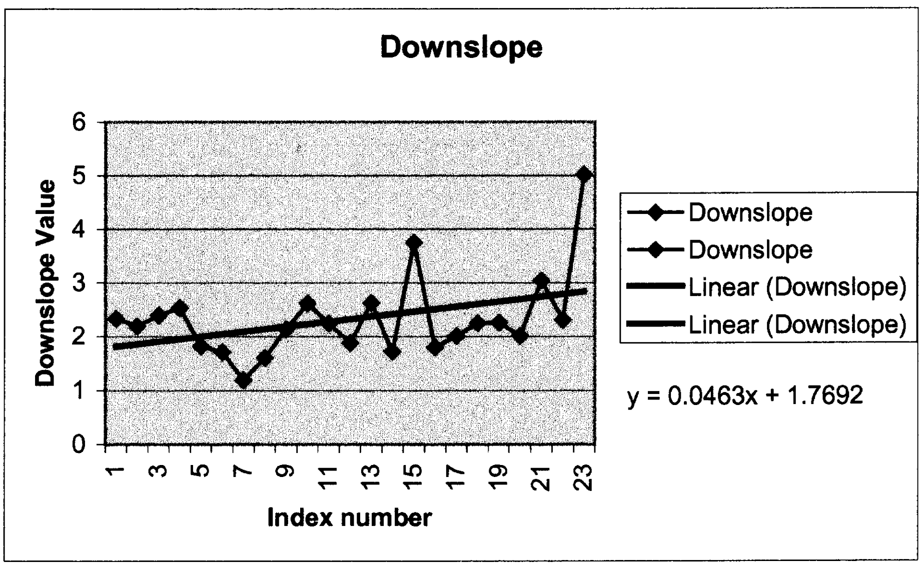


Figure 5.4 Graph showing the increase in downslope values.

A positive slope on the trend line denotes the increase in the downslope values, which indicates a faster recovery period as the cycles session progresses. A table shows the values of the downslope and their sessions for subject C25. The statistical t-test for subject C10 did not show any significant P (t<=T) values, so the t-test for another subject is considered and discussed.

Table 5.8 Downslope Values and Sessions for Subject C25

Week	**Time S1**	**Session1**	**Time S2**	**Session2**	**Time S3**	**Session3**
Baseline	10:54:02AM	2.082				
Week1	8:32:40 AM	1.274	8:40:48 AM	4.690	8:26:29 AM	1.759
Week2						
Week3			9:53:44 AM	1.900	9:55:11 AM	0.8899
Week4	9:56:08 AM	1.398	9:59:31 AM	0.6434	3:05:35 PM	0.9047
Week5	3:02:12 PM	0.7785				
Week6			9:31:27 AM	1.047		
Week7						
Week8						
Week9	3:59:44 PM	3.292	9:44:09 AM	2.111		
Week10	4:06:35 PM	0.7196	10:32:10AM	3.169	11:58:27AM	0.8991
Week11	2:57:01PM	1.744	4:02:45 PM	1.273		

Discussion: An increase in downslope values indicates that the subject has a faster recovery period. The deep breath further enhances the heart rate recovery via vagally mediated effect. Physiologically an increase in the downslope values indicates the heart's ability to recover from stress faster. An increase in downslope values is statistically proved by performing the t-test paired two sample for means. The initial and final values considered for this purpose is shown in table 5.9.

Table 5.9 Initial and Final Values of Downslope for Subject C10

InitialValues	Times	FinalValues	Times
1.274	8:32:40 AM	2.111	9:44:09 AM
1.759	8:26:29 AM	3.169	10:32:10AM
0.778	3:02:12 PM	1.744	2:57:01PM
0.904	3:05:35 PM	1.273	4:02:45 PM

The t-test Values are shown as below

Subject C25	**Variable 1**	Variable2
Mean	1.179179	2.074808
Variance	0.193743	0.650039
Observations	4	4
Pearson Correlation	0.930303	
HypothesizedMeanDifference	0	
Df	3	
T Stat	-4.18171	
P (T<=t) one-tail	0.012459	
T Critical one-tail	2.353363	
P (T<=t) two-tail	0.024918	
T Critical two-tail	3.182449	

Table 5.10 also shows the downslope value of all the subjects and a significant increase as the cycles session progresses. A t-test conducted on all the subjects' downslope values between the initial and the final week did not reveal any significant increase.

Table 5.10 Initial and Final Downslope Values of All Subjects

Subject	**Initial Values**	**Final Value**
C05	0.0527704	0.0658436
C08	2.36267	2.70018
C10	1.55474	5.08893
C15	1.61432	2.03218
C22	1.74949	2.57143
C25	1.67844	3.29995
C37	2.60236	2.45599
C53	1.21071	2.04731

The corresponding t-test values are shown below

All Subjects	**Variable 1**	Variable2
Mean	1.535872375	2.266896125
Variance	0.193743	0.650039
Observations	4	4
Pearson Correlation	0.930303	
HypothesizedMeanDifference	0	
Df	3	
T Stat	-4.18171	
P (T<=t) one-tail	0.047603498	
T Critical one-tail	2.353363	
P (T<=t) two-tail	0.095206005	
T Critical two-tail	3.182449	

5.3 Focused Breathing and Circadian Results

Focused Breathing Results: The focused breathing results were not consistent for subjects undergoing the cycles session. The data for the baseline, weeks 8, 16 and the end of sessions were unavailable. The data analysis was restricted due to the unavailability and also due to clubbing of circadian and focused breathing .The subjects underwent the first five minutes of focused breathing and then continued the circadian session. The circadian data is averaged over 5 seconds, but if the same is done with focused breathing, important information in the high and the low frequency power spectrum is lost. Thus, focused breathing data could not be recovered from the circadian data. The deep breath magnitude gives the analysis of heart rate variability.

Circadian Results: The circadian data results are governed by various external factors. Since this data collection is for 24-hours, the subjects are allowed to do their normal work. There were artifacts in the data when they were analyzed. Mostly the subjects lost their connection during data collection and so the data files had sets of zeroes. Circadian rhythm is a very good estimate of the subject's overall health and is an area, which could be focused in the near future.

5.4 Aerobics Results

The subjects are required to increase their heart rate as the session progresses. A graph showing an increase in the aerobics session is seen below. There were eight subjects chosen for this study and they were required to perform their normal exercise regimen. The subjects increase their heart rate as the session increases. In this case the subjects increase their heart rate to a specific value and maintain it followed by a single recovery period.

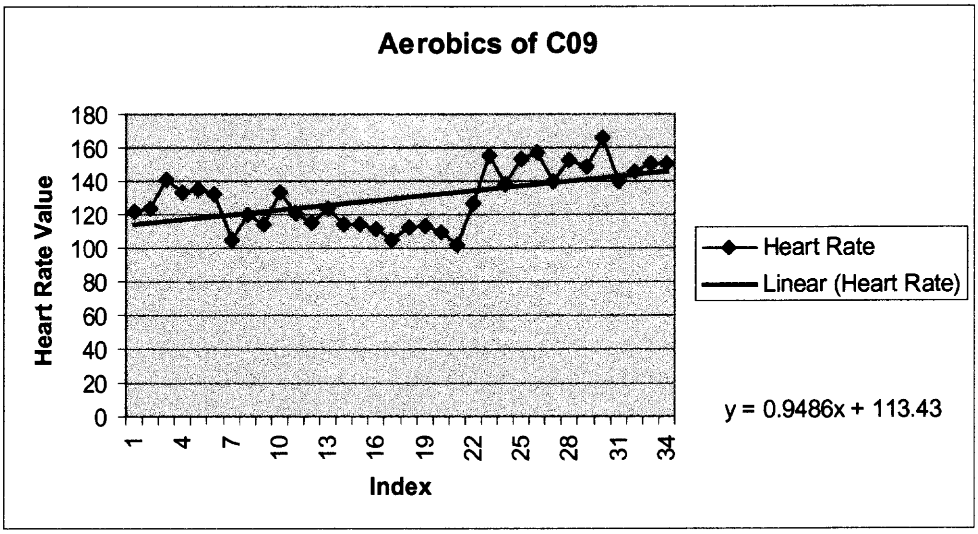


Figure 5.5 Increase of heart rate values in aerobics of subject c09.

An increasing target heart rate is confirmed by the positive slope displayed when the trend line is fitted on the curve. The aerobics data is for comparison with the cycles data. The aerobics subjects also undergo the focused breathing and the circadian session. Thus, a comparison is struck between the cycles and the aerobics to see the improvement of quality of life and the heart rate variability. Table 5.10 shows the values of heart rates achieved by each subject from the initial to the end of the aerobics session and a corresponding t-test is performed to demonstrate the significant increase in the heart rate value.

Table 5.11 Initial and Final Heart Rates for All Subjects in Aerobics

Subject	Initial Value	Final Value
C09	122.033	126.409
C11	155.686	150.015
C17	130.431	121.341
C18	130.122	154.009
C23	156.372	122.859
C27	137.186	115.582
C29	118.033	105.957
C54	162.467	123.444
C55	154.624	148.426
C56	148.444	140.087

The t-test values are shown below

All Subjects	Variable 1	Variable 2
Mean	141.5398	130.8129
Variance	253.6370177	264.3869377
Observations	10	10
Pearson Correlation	0.37364105	0.37364105
HypothesizedMeanDifference	0	
Df	9	
T Stat	1.88304099	
P (T<=t) one-tail	0.046178461	
T Critical one-tail	1.833113856	
P (T<=t) two-tail	0.092356922	
T Critical two-tail	2.262158887	

From the above t-test values, it is evident that the aerobics subjects show an increase in the heart rate value as the session progresses. This is confirmed statistically, because from the above table the value of $p=0.04<0.05$.

5.5 Insomnia Results and Discussion

This section discusses the results obtained in the Insomnia study. There are no morning sessions in this study and all the cycles sessions were conducted in the afternoon and the results are discussed in the form of graphs. Graphically, the results obtained in the AIDS study and the results obtained in the Insomnia study coincide.

Deep Breath Magnitude: There was not a consistent increase in the deep breath magnitudes but there was a small but significant increase from the beginning to the end of the session. This was confirmed by plotting the values and fitting a trend line. When the slope of the trend line was calculated, a positive slope confirmed an increase in the magnitude of the deep breath values. The graph below shows the increase in deep breath values of subject e17.

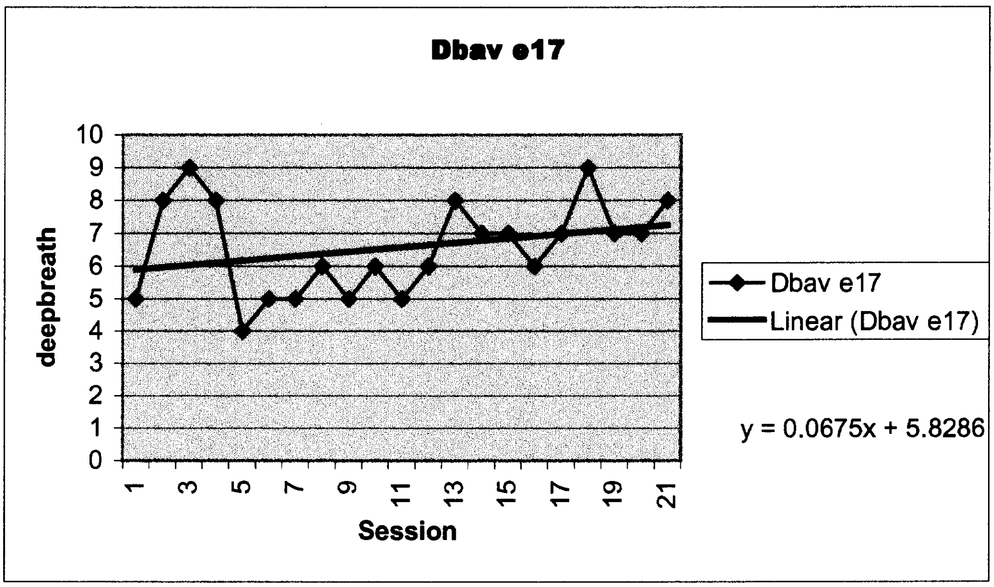


Figure 5.6 Graph showing an increase in deep breath magnitudes of subject e17.

Discussion: The results obtained in the insomnia study also coincide with that of the AIDS study for the deep breath parameter. There was a small but significant increase in deep breath value. This is of considerable importance because; the deep breath enhances the training recovery, which in turn enhances parasympathetic activity and hence heart rate variability. Deep breath magnitude is a direct indicator of heart rate variability. A significant increase in the value of the deep breath is proved by means of a t-test conducted between the initial and the final deep breath parameters from the beginning. Table 5.12 shows the initial and final values of deep breath taken at the beginning and at the end of the session for all the subjects, respectively.

Table 5.12 Initial and Final Values of Deep Breath for All Subjects

Subject	**Initial Value**	**Final Value**
E04	8	10
E11	9	8
E17	5	8
E18	8	11
E21	6	15
E22	9	8
E23	7	9
E26	9	7
E27	6	11
E28	7	14
E30	4	8

From the t-test values, it is evident that the results of the Insomnia study coincide with that of the AIDS study where there is an increase in the deep breath magnitudes. Statistical significance for deep breath in this case is $p = 0.02 < 0.05$. Thus, an increase in the deep breath values indicates an increase in the heart rate variability.

The t-test reveals the following significance

All Subjects	**Variable 1**	**Variable 2**
Mean	7.09090909	9.909090909
Variance	253.6370177	264.3869377
Observations	11	11
Pearson Correlation	0.37364105	0.37364105
HypothesizedMeanDifference	0	
Df	9	
T Stat	1.88304099	
P (T<=t) one-tail	0.010263	
T Critical one-tail	1.833113856	
P (T<=t) two-tail	0.020526	
T Critical two-tail	2.262158887	

Upslope values: Upslope parameter is the acceleration phase of the cycles and the figure 5.6 showing the increase in the upslope values is shown below of subject e18. As seen from the AIDS study the upslope parameter increases as the cycles session progresses.

Discussion: An increase in the upslope parameter indicates that the subject is able to reach the target heart rates easily. This is an important parameter of progress in the cycles session. Physiologically an increase in the upslope values indicates the heart's ability to respond to stress faster. A trend line is fitted on the curve and the slope of the line is calculated and displayed. The increasing upslope is confirmed by the fact that the fitted line has a positive slope. The Table 5.12 shows the initial and final upslope values of all subjects at the beginning and the end of the session. A t-test statistically did not reveal a significant increase in the upslope values and the value of $p = 0.0984 > 0.05$.

Table 5.13 Initial and Final Upslope Values for All Subjects

Subject	Initial Value	Final Value
E04	2.619	2.714
E11	2.047	2.714
E17	2.761	2.333
E18	2.047	3.190
E21	4.023	4.095
E22	3.619	2.714
E23	3.380	4.190
E26	1.285	3.142
E27	4.333	4.142
E28	1.190	2.190
E30	1.619	2.285

T-test values for the above table is shown below

All Subjects	Variable 1	Variable 2
Mean	2.629870364	3.064937273
Variance	1.198337805	0.578810087
Observations	11	11
Pearson Correlation	0.690507146	
HypothesizedMeanDifference	0	
Df	10	
T Stat	1.822303069	
P (T<=t) one-tail	0.049203006	
T Critical one-tail	1.812461505	
P (T<=t) two-tail	0.098406013	
T Critical two-tail	2.228139238	

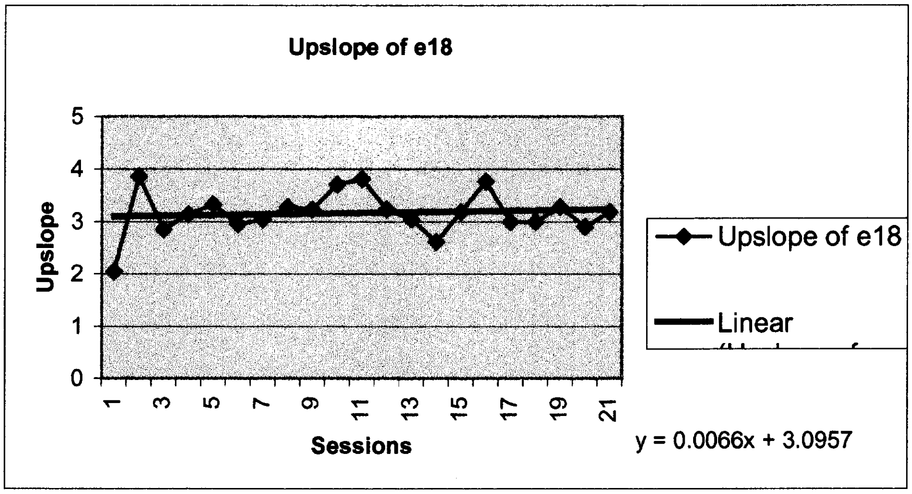


Figure 5.7 Graph showing an increase in the upslope values of subject e18.

Downslope Values: Downslope is the recovery phase of the cycle. An increase in the downslope values of subject e04 is graphically shown below in figure5.7. This is an important parameter of progress in terms of recovery.

Discussion: An increase in downslope values indicates that the subject has a faster recovery period. Physiologically recovery is a dynamic process, mediated by the parasympathetic nervous system and it denotes the ability of the heart to recover form stress faster. Since this recovery is enhanced, this results in greater neuro autonomic plasticity, which in turn enhances healthy function. A trend line is fitted on the graph and the slope is calculated and displayed. It is obvious from the positive slope that there is an increase in the value of the downslope. Table 5.14 below shows the downslope values of all subjects and its corresponding t-test that denotes a significant increase. Significance is $P = 0.000761 < 0.05$.

Table 5.14 Initial and final Downslope Values of all Subjects

Subject	Initial Value	Final Value
E04	2.904	3.523
E11	2.142	2.285
E17	1.619	2.333
E18	2.095	3.047
E21	2	3.714
E22	2.142	2.047
E23	2.047	3.238
E26	1.190	2.476
E27	3.142	3.333
E28	1.557	1.952
E30	1.095	2.714

t-test for significance is shown below

All Subjects	Variable 1	Variable 2
Mean	1.994373636	2.787879091
Variance	0.399168887	0.377490874
Observations	11	11
Pearson Correlation	0.520370659	
HypothesizedMeanDifference	0	
Df	10	
T Stat	4.311081318	
P (T<=t) one-tail	0.000767235	
T Critical one-tail	1.812461505	
P (T<=t) two-tail	0.001534469	
T Critical two-tail	2.228139238	

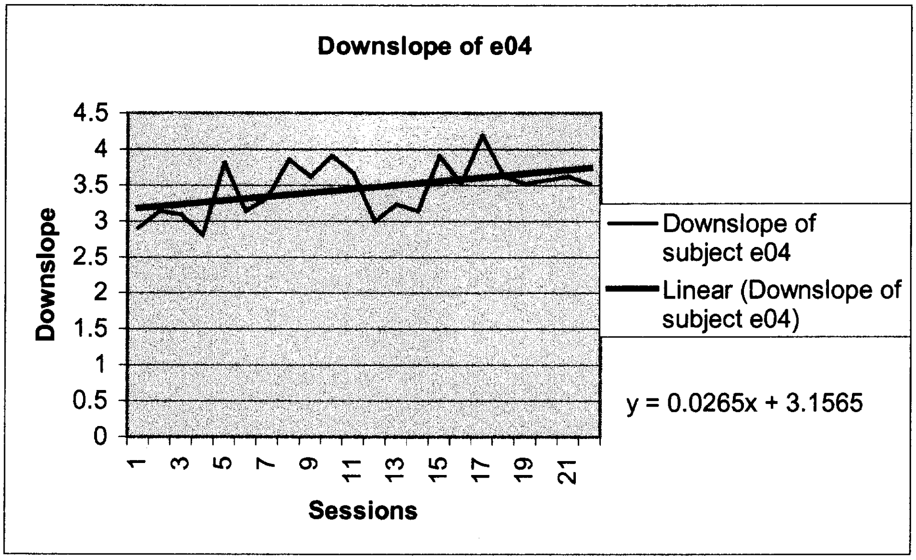


Figure 5.8 Graph showing an increase in the downslope values.

Slope base Values: This variable denotes the rise in the baseline of the heart rate signal from the prior to the completion of the session. This is an important measure of progress. The graph 5.8 shows the increase the slope base parameter of the subject e04.

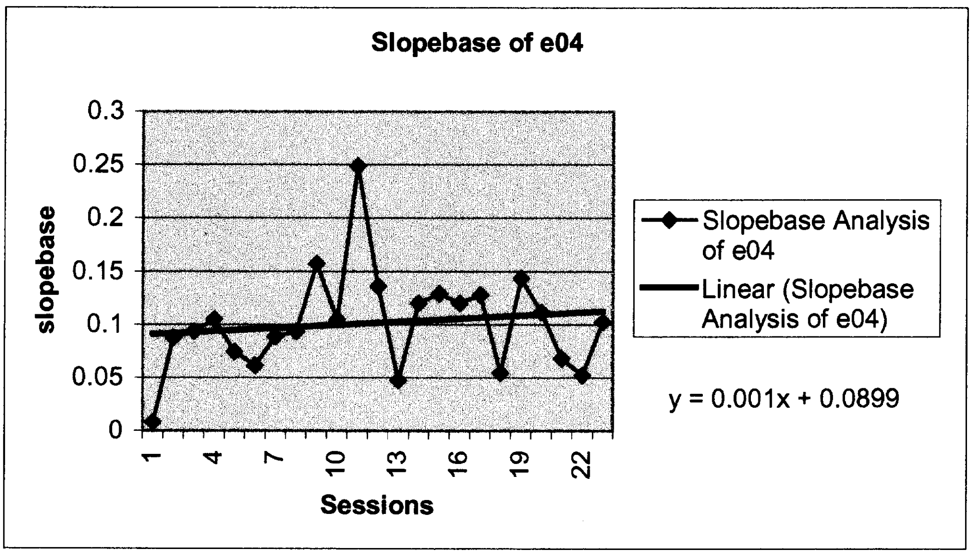


Figure 5.9 Increase in slope base values of subject e04.

Discussion: The reason why the slope base parameter is of utmost importance is because; an increase in magnitude of the slope base value indicates an increase in the magnitude of the ultradian rhythm. Ultradians are waves of 1.5-hour duration that make up the larger wave – the circadian rhythm. Table 5.14 shows the slope base values of all the subjects in the insomnia study. A t-test did not reveal a significant increase in the values. The results of the slope base parameter did not coincide with that of the AIDS study. In other words, the increase in the magnitude of the slope base value is projected on the circadian rhythm as an increase in the magnitude of the ultradian rhythm. In case of Insomnia study there were no circadian data to estimate the overall health of the subject.

A t-test to test the statistical significance of the slope base parameter did not reveal an increase in the value. The value of $p = 0.233231926 > 0.05$. Although the t-test did not reveal a significant increase, the graph showed an increase in the upslope value and this was evident from the positive slope of the trend line fitted on the slope base curve.

Table 5.15 Initial and Final Values of Slope base for All Subjects

Subject	**Initial Value**	**Final Value**
E04	2.904	3.523
E11	2.142	2.285
E17	1.619	2.333
E18	2.095	3.047
E21	2	3.714
E22	2.142	2.047
E23	2.047	3.238
E26	1.190	2.476
E27	3.142	3.333
E28	1.557	1.952
E30	1.095	2.714

A t- test for the above table for slope base values is shown below

All Subjects	**Variable 1**	**Variable 2**
Mean	0.099699855	0.120236109
Variance	0.005290524	0.001728848
Observations	11	11
Pearson Correlation	0.684106395	
HypothesizedMeanDifference	0	
Df	10	
T Stat	1.268853272	
P (T<=t) one-tail	0.116615963	
T Critical one-tail	1.812461505	
P (T<=t) two-tail	0.233231926	
T Critical two-tail	2.228139238	

CHAPTER 6

CONCLUSIONS, LIMITATIONS AND FUTURE PROGRESS

6.1 Conclusion

Implementation of the Cycles Exercise Protocol on two study groups has yielded similar results. This exercise protocol requires very little exertion, about 40 minutes a month and the rest of the time is spent in recovery. Thus, the exertion and recovery are trained together as a cycle. Since the cycles session requires very little exertion, the session can be scheduled and performed everywhere even at work. The cycles train the body to quickly respond to stress and recover. An increase in the deep breath magnitudes of the subject indicates an increase in the training recovery. This increase in training recovery enhances parasympathetic activity and hence the heart rate variability. The slope base parameter also showed a significant increase in case of the AIDS study implying an increase in the ultradian rhythm therefore the circadian rhythm. The deep breath magnitudes that provided an alternative to the focused breathing data showed an increase in the magnitudes but did not show any significance in the t-test in the AIDS study. This was mainly due to the fact that the focused breathing and the circadian data that was averaged every five seconds were combined. As a result, information in the low frequency, high frequency and very low frequency were lost because (a) sampling rate was low and (b) there was one point every five seconds – 12 breaths per minute. This caused a major loss of the focused breathing data rendering the files unusable.

The Insomnia study showed significant increase in the deep breath magnitudes thereby indicating an increase in the heart rate variability. This has physiological impact on the heart thereby improving the overall health of the body. Since recovery is an important aspect of the cycles program, an increase in the downslope values in the Insomnia study that indicate faster recovery are also noted. An increase in the downslope values in the insomnia study indicates the subjects recover quickly therefore an increases rate of recovery and hence this trained the body's recovery process. An increase in the deep breath magnitudes also increases recovery through a vagally mediated effect. Although many parameters in the AIDS and the Insomnia study did not show any significant increase, they showed a positive trend. Aerobics studies also showed an increase in the heart rate value as the session progressed. The aerobics data was used for comparison of cycles data. The other physiological tests also yielded positive results and hence considerable improvement in the subject's health. Thus, cycles with minimum exertion confers maximum benefits to the body.

6.2 Limitations

There are a number of limitations in the study. Since the data came from an on going pilot study, sometimes the protocol was not followed and hence there were problems encountered during data analysis. In case of the Insomnia study, the subjects did not rest for a long enough time after the final cycle. Hence the calculation of the post base value had problems and had to be redefined. In the AIDS study, the focused breathing and the circadian rhythm data were combined. In the latter half of the study, the first five minutes of the circadian data was focused breathing. The circadian and the focused breathing data were averaged every 5 seconds. Due to this, the information in the heart rate power spectrum while analyzing the focused breathing data is lost. Due to this the data files were rendered unusable for focused breathing. Thus, a direct measurement of heart rate variability was not possible. In case of circadian data, sometimes the data was not collected for 24 hours. Also, if the connectivity between the subject and the polar heart rate monitor was lost, the data was not recorded and hence huge pieces of data were missing. While measuring deep breath magnitudes, sometimes, the subjects failed to push the button correctly or they did not push the button at all. Hence the calculation of deep breath values became difficult.

Despite these limitations, there were positive results for deep breath, upslope, downslope and the slope base parameters that were discussed in detail in earlier chapters. If these limitations are overcome, the cycles exercise protocol definitely has an edge over the regular exercise regimen and will help every individual, diseased or healthy to improve their overall health.

6.3 Future Progress

The next step of this study is to see if the work done by both cycles and the aerobics are the same by calculating the area under each of the curve. By calculating the area under the curve, it can be hypothesized that although the cycles exertion is less, the work done and hence the energy expended is the same in both cases. The next step would be to concentrate more on the circadian data and focused breathing and yield results. The next step would be to implement this protocol in healthy men under my supervision and rule out any shortcomings that might occur due to improper protocol implementation or data collection. If the limitations as discussed in the previous chapter are solved, this protocol involving less than 40 minutes of exertion a month can be implemented in all types of patient populations.

This protocol is not targeted at any organ in particular and is aimed at improving the inherent 24- hour cycle of the body, this protocol is bound to be a success in all patient groups. The next step would be to investigate the fractal behavior of the of body waves down to the cellular level. If implemented successfully, this protocol will definitely revolutionize the traditional exercise regimen. Also, every unit in the hospital will have a circadian rhythm monitor by the side of each patient to monitor the circadian rhythm of patients undergoing the cycles protocol.

APPENDIX A

BORG'S SCALE AND KARVONEN FORMULA

A.1 Introduction

The appendix shows the Borg's perceived scale of exertion based on which the exertion level of the cycles subjects are determined. This also shows the calculation of heart rate using the Karvonen's formula for the determination of target heart rate in the aerobics session. The figure below shows the Borg's perceived scale of exertion.

6	Very, very light
7	
8	
	Very light
9	
10	
	Fairly light
11	
12	
	Somewhat hard
13	
14	
15	Hard
16	
17	
	Very hard
18	
19	
	Very very hard
20	

Figure A.1 The Borg scale of perceived exertion.

The original Borg scale of perceived exertion has been modified. The number from 6 to 10 are in green, the numbers from 11 to 15 are in yellow, and the numbers from 16 to 20 are in red, similar in concept to traffic lights.

A.2 The Karvonen Formula

The Karvonen's Formula is an accurate way to calculate your desired aerobic training intensity. The required information:

1. Your age in years.
2. Resting Heart Rate – in beats per minute. Take your resting heart rate in the morning.
3. Lie quietly and take a one-minute pulse. Do this for three mornings in a row to record the average.
4. Percentage of Maximum Heart Rate. The American College of Sport Medicine recommends exercising between 60% and 90% of your Maximum Heart Rate.

A.3 Heart Rate Calculation

To obtain maximum benefits from exercise it is best to work at a predetermined heart rate.

Taking your Pulse

The pulse is most commonly taken either at the carotid artery on the neck or at the wrist. Use your index finger and middle finger to locate your pulse (never use your thumb). Use a very light touch and avoid pressing too hard. You may use a 6 or 10 second pulse check, then multiply by the appropriate number (10 or 6 respectively) to get a 60 second count.

Maximum heart rate: 220

This heart rate generally declines with age from about 220 beats per minute in childhood to about 160 beats per minute at age 60. This fall in heart rate is fairly linear, decreasing by approximately 1 beat per minute per year. There is no strong evidence to suggest that training influences the decline in maximal heart rate. It should be remembered that individuals of the same age might have quite different maximal heart rates. Therefore it is more accurate to calculate this value by undergoing a stress test than by using an age-related formula. On the other hand, resting heart rate is greatly influenced by endurance training.

Resting Heart Rate

This is your heart rate at complete rest. To determine this, take your pulse for 60 seconds just before you get out of bed...or take it for 30 seconds and multiply by 2. The typical adult has a resting heart rate of about 72 bpm whereas highly trained runners may have readings of 40 bpm or lower.

Target Heart Rate Range

Training intensity should range from 40% - 85% of adjusted maximal heart rate. Beginning exercisers should work between 50% - 65%. More advanced exercisers may be comfortable in the 70% - 80% range. Very fit exercisers may tolerate a level up to 85%.

Final Calculation

For your age, use a whole year. (Between 0 and 100)

Put your Resting Heart Rate. (Between 30 and 100)

Enter your maximum heart rate if you know it (use a number between 50 and 85) Otherwise use an estimate as follows:

Males: 214 - (0.8*age).

Females: 209 - (0.7*age).

Calculate your target heart rate using the Karvonen's formula

APPENDIX B

PROGRAMS FOR DATA ANALYSIS

B.1 Introduction

This section discusses the Mathematica and the Labview programs used for data analysis. Cycles, circadian and aerobics data were analyzed using mathematica programs and the focused breathing data was analyzed using lab view.

B.2 Mathematica Programs

Cycles Program

This program written by Dr. Stanley Reisman is a modified version by Ann Marie Petrock and Ujwala.G.Kalambur (Mathematica Version 4.1)

```
cb = Import["c10week2session351702.hrm", "Text"];
cycleb = cb; c=StringDrop [cycleb, (Part[Part[StringPosition[cycleb, "[HRData]"], 1], 2]
+ 1)];b = StringToStream[c]; a = ReadList[b, Number];Close[b]; cycle = {}; cyclea = {};
Do[If[a[[i]] == 9999, 0, cycle = Append[cycle, a[[i]]]], {i, 1, Length[cycleb]}];
(****Conversion of IBI data in milliseconds to Heart rate data in beats per minute. Not
present in case of 5 second files ******)
a1 = N[60000/a]; cycleb = a1;
(****Initialize output variables*)
dnslop = -10.0; dbav= -10.0; base = -10.0; slopebase = -10.0; postbase = -10.0; upslop = -
10.0; maxcycle = -10.0; nogoal = -10.0; status = -10.0; pospk = {-10.0,
-10.0}; posmn = {-10.0, -10.0}; totalerror = {-10.0}; lefterror = {-10.0}; righterror = {-
10.0}; cflist = {-10.0};
(********Remove points outside the range 29 - 231**********)
Do[If[cycleb[[i]] > 28[And] cycleb[[i]] < 232,cyclea = Append[cyclea, cycleb[[i]]]], {i,
1,Length[cycleb]}]; cycle = cyclea;
If[Length[cycle] < 40, Goto[skip1]];
(******Program the time counter*********)
tj = Table[0, {Length[cycle]}];
N[tj[[1]] = 60/cycle[[1]]];
Do[tj[[n]] = tj[[n - 1]] + 60/cycle[[n]], {n, 2, Length[cycle]}];ti = N[tj];
(**********Spike Detector**************)
cycle[[1]] = N[1/8]*Sum[cycle[[i]], {i, 2, 9}];
cycle2d = Table[0, {i, Length[cycle]}, {j, 2}]; Do[cycle2d[[i, 1]] = i, {i, Length[cycle]}];
```

```
Do[cycle2d[[i, 2]] = cycle[[i]], {i, Length[cycle]}];
spst = {First[cycle2d]};Do[If[(cycle[[i]] - cycle[[i - 1]]) > 60,spst = Append[spst, cycle2d[[i]]]], {i, 2, Length[cycle]}];spst1 = Drop[spst, 1];
spend = Table[0, {Length[spst1]}];fend[j_] := (Catch[Do[i; If[cycle[[i]] != spst1[[j, 2]], Throw[i]], {i, spst1[[j, 1]],Length[cycle]}]]);Do[spend[[j]] = fend[j], {j, 1, Length[spst1]}]; freplace[j_] := (For[i = spst1[[j, 1]], i < spend[[j]], i++, cycle2d[[i, 2]] = cycle2d[[(spst1[[j, 1]] - 1), 2]]]);Do[freplace[j], {j, 1, Length[spst1]}];
(*********Dropout Detector**************)
cycle2d[[1, 2]]=N[1/Length[cycle2d]]*Sum[cycle2d[[i, 2]], {i, 1, Length[cycle2d]}];
zp = {cycle2d[[1, 1]]}; Do[If[cycle2d[[i, 2]] == 0, zp = Append[zp, cycle2d[[i, 1]]]], {i, 2,Length[cycle2d]}];If[Length[zp] == 1, zp = Join[zp, {9999}]];
zp1 = Drop[zp, 1]; szp = {First[zp1]};
ezp = szp;Do[If[(zp1[[i + 1]] - zp1[[i]]) > 1, (szp = Append[szp, zp1[[i + 1]]];
ezp = Append[ezp, zp1[[i]]])], {i, 2, Length[zp1] - 1}];
ezp = Append[ezp, zp1[[Length[zp1]]]];
ezp1 = Drop[ezp, 1]; If[szp == {9999}, Goto[nd]];
fzero[j_] := (For[i = szp[[j]], i < 1 + ezp1[[j]], i++,cycle2d[[i, 2]] = cycle2d[[szp[[j]] - 1, 2]]]); Do[fzero[j], {j, 1, Length[szp]}]; Label[nd];
(**********End of spike dropout section. Results in cycle2d*******)
Do[cycle[[i]] = cycle2d[[i, 2]], {i, Length[cycle2d]}];
cycle3d = Table[0, {i, Length[cycle]}, {j, 3}];
Do[cycle3d[[i, 1]] = i, {i, Length[cycle]}];
Do[cycle3d[[i, 2]] = cycle[[i]], {i, Length[cycle]}];
Do[cycle3d[[i, 3]] = ti[[i]], {i, Length[cycle]}]; m =
Floor[N[Length[cycle]/5]];(*Max Detector*)
(*******Take average of every five point***********)
fifth = Table[0, {m}];
Do[ fifth[[i]] = 0.2*(cycle[[5*i - 4]]+cycle[[5*i - 3]]+cycle[[5*i - 2]]+cycle[[5*i - 1]] + cycle[[5*i]]), {i, 1, m}];
cycle = fifth; padded = Join[Table[0, {10}], cycle, Table[0, {10}]];
smooth = Table[0, {Length[cycle]}];
l=Length[cycle]-11;
Do[ smooth[[j]] = N[1/21]*Sum[cycle[[i]], {i, j - 10, j + 10}], {j, 11, l}];
smooth1 = Take[smooth, {11, l - 10}];
padded1 = Join[Table[0, {6}], smooth1];
ld = Table[0, {Length[smooth1]}];
Do[ld[[i]] = smooth1[[i]] - smooth1[[i - 6]], {i, 6, Length[smooth1]}];
ld1 = Drop[ld, 6 ];
mx = Max[ld1];
mn = Min[ld1];
test = Table[0, {i, Length[ld1]}, {j, 2}];
Do[test[[i, 1]] = i, {i, Length[ld1]}];
Do[test[[i, 2]] = ld1[[i]], {i, Length[ld1]}];
pd = First[test];
Do[If[test[[i, 2]] > 0.4*mx, pd = Append[pd, test[[i]]]], {i, 1,Length[test]}]; If[Length[pd] < 3, Goto[skip1]];
```

```
pd1 = Drop[pd, 2]; pd1;
nd = First[test];
Do[If[test[[i, 2]] < 0.4*mn, nd = Append[nd, test[[i]]]], {i, 1,Length[test]}];
If[Length[nd] < 3, Goto[skip1]];
nd1 = Drop[nd, 2]; nd1;
p1 = Table[0, {Length[pd1]}];
Do[p1[[i]] = pd1[[i, 1]], {i, 1, Length[pd1]}];
n1 = Table[0, {Length[nd1]}];
Do[n1[[i]] = nd1[[i, 1]], {i, 1, Length[nd1]}];
p = {First[p1]};
Do[If[(p1[[i + 1]] - p1[[i]]) > 20, p = Append[p, p1[[i]]]], {i, 1,Length[p1] - 1}];
If[p1[[Length[p1]]] - p1[[Length[p1] - 1]] > 20,p = Append[p, p1[[Length[p1]]]]]; p =
Append[p, p1[[Length[p1]]]];
n = {First[n1]};
Do[If[(n1[[i + 1]] - n1[[i]]) > 20, n = Append[n, n1[[i]]]], {i, 1,Length[n1] - 1}];
If[n1[[Length[n1]]] - n1[[Length[n1] - 1]] > 20,n=Append[n, n1[[Length[n1]]]]]; n =
Append[n, n1[[Length[n1]]]];
p = Drop[p, 1];
n = Drop[n, 1];
(********Take pk positions*****************)
mintab1 = Table[0, {i, Length[peakpos]}, {j, 2}];
Do[mintab1[[i, 1]] = Range[peakpos[[i]] - 15, peakpos[[i]]], {i, 1, Length[peakpos]}];
cycledat = Table[0, {Length[cycle1]}];Do[cycledat[[i]] = cycle1[[i, 2]], {i, 1,
Length[cycle1]}]; Do[mintab1[[i, 2]] = Take[cycledat, {peakpos[[i]] - 15, peakpos[[i]]}],
{i, 1, Length[peakpos]}];newmin = Table[0, {i, Length[peakpos]}, {j, 2}];
Do[newmin[[i, 1]] = Min[mintab1[[i, 2]]], {i, 1, Length[peakpos]}];
newmin1 = Table[0, {Length[peakpos]}]; min = Table[0, {Length[peakpos]}];
Do[min[[i]] = Position[mintab1[[i, 2]], newmin[[i, 1]]], {i, 1, Length[peakpos]}];
Do[newmin1[[i]] = Last[min[[i]]], {i, 1, Length[peakpos]}];
min = Flatten[newmin1]; Do[newmin[[i, 2]] = min[[i]], {i, 1, Length[peakpos]}];
minpos = Table[0, {Length[peakpos]}]; minpos = mintab1[[All, 1]];
minpos1 = Table[0, {Length[peakpos]}]; Do[minpos1[[i]] = Take[minpos[[i]], {min[[i]],
min[[i]]}], {i, 1, Length[peakpos]}];minpos2 = Flatten[minpos1]; Do[newmin[[i, 2]] =
minpos2[[i]], {i, 1, Length[peakpos]}];
(***************Min Detector*********************)
mn = Table[0, {Length[mx3]}];
smooth2 = Table[0, {i, Length[smooth1]}, {j, 2}];
Do[smooth2[[i, 1]] = i, {i, Length[smooth1]}];
Do[smooth2[[i, 2]] = smooth1[[i]], {i, Length[smooth1]}];
fmn[j_] := (If[mx3[[j, 1]] < 80, smooth3 = Take[smooth2, {1, mx3[[j, 1]]}],
smooth3 = Take[smooth2, {mx3[[j, 1]] - 80, mx3[[j, 1]]}]];
smoothe4 = Table[0, {Length[smooth3]}]; Do[smoothe4[[i]] = smooth3[[i, 2]], {i, 1,
Length[smooth3]}]; mn2 = Min[smoothe4]; mn1 = Catch[Do[i; If[mn2 == smoothe4[[i]],
Throw[i]], {i, 1,Length[smoothe4]}]]; mn[[j]] = smooth3[[mn1]]);Do[fmn[j], {j, 1,
Length[mx3]}];
```

```
(******Find Deep Breath pk - pk value using Button Push Information****)
db1 = Table[0, {Length[dbodd]}]; Do[db1[[i]] = Take[cycle1num, {dbodd[[i]], 10 + dbodd[[i]]}], {i, 1, Length[dbodd]}]; dbmax = Table[0, {Length[dbodd]}];
Do[dbmax[[i]] = Max[db1[[i]]], {i, 1, Length[dbodd]}];
pdbmax = Table[0, {Length[dbodd]}]; Do[pdbmax[[i]] = Position[db1[[i]], dbmax[[i]]], {i, 1, Length[dbodd]}]; Do[pdbmax[[i]] = First[pdbmax[[i]]], {i, 1, Length[dbmax]}];
pdbmax = Flatten[pdbmax];dbmin = Table[0, {Length[dbodd]}];
Do[dbmin[[i]] = Min[db1[[i]]], {i, 1, Length[dbodd]}]; pdbmin = Table[0, {Length[dbodd]}];Do[pdbmin[[i]] = Position[db1[[i]], dbmin[[i]]], {i, 1, Length[dbodd]}]; Do[pdbmin[[i]] = First[pdbmin[[i]]], {i, 1, Length[dbmin]}];
pdbmin = Flatten[pdbmin];dbminpos = Table[0, {Length[dbodd]}];
Do[dbminpos[[i]] = dbodd[[i]] + pdbmin[[i]], {i, 1, Length[pdbmin]}];
dbpp = Table[0, {Length[dbodd]}]; Do[dbpp[[i]] = (dbmax[[i]] - dbmin[[i]]), {i, 1, Length[dbodd]}];dbav=Round[N[1/Length[dbpp]]*Sum[dbpp[[i]], {i, 1, Length[dbpp]}]]; Label[cycnoBP];
(*******Calculate parabola cycles fit**********)
p = Table[0, {Length[mx3]}]; Do[p[[i]] = mx3[[i, 1]], {i, Length[mx3]}];
test = Table[0, {i, Length[cycle]}, {j, 2}]; Do[test[[i, 1]] = i, {i, Length[cycle]}];
Do[test[[i, 2]] = cycle[[i]], {i, Length[cycle]}]; try = Table[0, {Length[p]}]; parab = Table[0, {Length[p]}]; Do[(try[[j]] = Take[test, {p[[j]] - 5, p[[j]] + 5}]; parab[[j]] = Fit[try[[j]], {1, x, x^2}, x]), {j, 1, Length[p]}]; cflist = CoefficientList[parab, {x}];
try1 = try; Do[try1[[j, i, 1]] = try[[j, i, 1]] - p[[j]], {i, 1, 11}, {j, 1, Length[p]}];
(*********Shift to y axis and fit*************)
parab0 = Table[0, {Length[p]}]; Do[parab0[[j]] = Fit[try1[[j]], {1, x, x^2}, x], {j, 1, Length[p]}]; CoefficientList[parab0, {x}];
(***********Compute error measures***********)
fit = Table[0, {Length[p]}]; Do[fit[[i]] = Table[parab0[[i]], {x, -5, 5}], {i, 1, Length[p]}];
error = Table[0, {i, Length[p]}, {j, 11}]; Do[error[[i, j]] = try1[[i, j, 2]] - fit[[i, j]], {i, 1, Length[p]}, {j, 1,11}]; totalerror = Table[0, {Length[p]}];lefterror = totalerror;
righterror = totalerror; Do[totalerror[[i]] = Sum[Abs[error[[i, j]]], {j, 11}], {i, Length[p]}]; Do[lefterror[[i]] = Sum[Abs[error[[i, j]]], {j, 1, 6}], {i, Length[p]}];
Do[righterror[[i]] = Sum[Abs[error[[i, j]]], {j, 6, 11}], {i, Length[p]}];
(****Calculations****)
Label[skip];
pospk = mx3; num = 0; Do[If[pospk[[i + 1, 1]] == pospk[[i, 1]], num = num + 1], {i, 1, Length[pospk] - 1}]; pospkln = Length[pospk] - num;Do[If[pospk[[i + 1, 1]] == pospk[[i, 1]], pospk = Drop[pospk, {i}]], {i, 1, pospkln - 1}];posmn = mn; num1 = 0;
Do[If[posmn[[i + 1, 1]] == posmn[[i, 1]], num1 = num1 + 1], {i, 1,
Length[posmn] - 1}]; posmnln = Length[posmn] - num1;
Do[If[posmn[[i + 1, 1]] == posmn[[i, 1]], posmn = Drop[posmn, {i}]], {i, 1,
 posmnln - 1}];base = Round[N[1/50]*Sum[cycle[[i]], {i, 1, 50}]];
l = Length[posmn];p = cycle3d[[posmn[[l, 1]], 3]] - cycle3d[[posmn[[1, 1]], 3]];
nogoal = mx3[[Length[mx3], 2]]; l1 = Length[pospk];
```

```
(*New calculation of post baseline.Assume 3 minutes (36 points)of data starting 2 minutes after the lastpeak*)
postbasepos = 24 + mx3[[Length[mx3], 1]];If[Length[cycle] < 36 + postbasepos, postbase = 0,postbase = Round[N[1/36]*
Sum[cycle[[i]], {i, postbasepos,36 + postbasepos}]]];
(***Assume that the position for the prebase is 1 minute before the first peak****)
(*****It should be at the button push for thefirst cycle***)
prebasepos = mx3[[1, 1]] - 12;slopebase = N[(postbase - base)/(postbasepos - prebasepos)]; status = Round[pospk[[l1, 2]] + 100*slopebase]; a = Table[0, {20}];Do[a[[i]] = smooth1[[pospk[[l1, 1]] + 1 - i]] - smooth1[[pospk[[l1, 1]] - i]], {i,1, 20}]; upslop = Max[a]; b = Table[0, {20}]; If[pospk[[l1, 1]] + 20 > Length[smooth1], m = Length[smooth1] - pospk[[l1, 1]], m = 20]; Do[b[[i]] = smooth1[[pospk[[l1, 1]] - 1 + i]] - smooth1[[pospk[[l1, 1]] + i]], {i,1, m}]; dnslop = Max[b]; Label[skip1]; cycle2d =Transpose[{Range[Length[cycle]]/12, cycle}]; {peakTimes, peakValues} = Transpose[pospk]; peakTimes /= 12.; a = 90; b = 50; c = 200; l = Length[cycle]/12; If[l < 60, a = 60]; If[Max[cycle] > 200, c = 15 + Max[cycle]]; If[Min[cycle] < 50, b = Min[cycle] - 15];
(****Plotting of Graphs****)
plot1 = ListPlot[cycle2d, PlotJoined -> True,
AxesLabel -> {"Time in Minutes", "Heart Rate"}, DefaultColor -> RGBColor[1, 1, 1],
PlotStyle -> {RGBColor[1, 1, 1], Thickness[0.01]}, TextStyle -> {FontFamily -> "Helvetica", FontSize -> 13, FontSlant -> "Italic", FontColor -> RGBColor[1, 1, 1]},
Background -> RGBColor[0.398, 0.398, 0.598], PlotLabel -> "Cycles Graph",
PlotRange -> {{0, a}, {b, c}}]; goal = {121, 131, 141, 151, 161, 166, 170,175};
plot2 = Graphics[{Table[Text[ToString[peakValues[[i]]] <> "/" <>
ToString[goal[[i]]], {peakTimes[[i]] - 1,
15 + peakValues[[i]]}], {i, Length[pospk]}],
Text["Lifewaves International LLC", {1/2, 47}]}];
Show[plot1, plot2, ImageSize -> {800, Automatic}]
dbav
pospk
posmn
base
slopebase
postbase
upslop
dnslop
totalerror
lefterror
righterror
maxcycle
nogoal
cflist
Status
```

Mathematica Program for Aerobics

```
data = Import["c17week9session1.hrm", "Text"];
Needs["Statistics`DataSmoothing`"];Needs["Statistics`DescriptiveStatistics`"];
cycleb = data; c = StringDrop[cycleb, (Part[Part[StringPosition[cycleb, "[HRData]"], 1], 2] + 1)]; b = StringToStream[c]; a = ReadList[b, Number]; a1 = N[60000/a]; aero = N[MovingAverage[a1, 50]];
(****Average of Heart Rate ****)
avglist = Take[a1, {900, 2800}]; peak = Max[avglist]; average = Mean[avglist];
output = {average};
(****Plotting of Graph****)
ListPlot[aero, PlotJoined -> True, AxesLabel -> {"Time in Minutes", "Heart Rate"},
DefaultColor -> RGBColor[1, 1, 1],PlotStyle -> {RGBColor[1, 1, 1], Thickness[0.005]},
TextStyle -> {FontFamily -> "Helvetica", FontSize -> 13,
FontSlant -> "Italic", FontColor -> RGBColor[1, 1, 1]}, Background -> RGBColor[0.398, 0.398, 0.598], PlotLabel -> "Aerobics Graph"]
Average
```

Mathematica Program for Circadian

This program is a modified version of the original work of Ann Marie Petrock
% Modified by Ujwala.G.Kalambur (Mathematica Version 5.1)

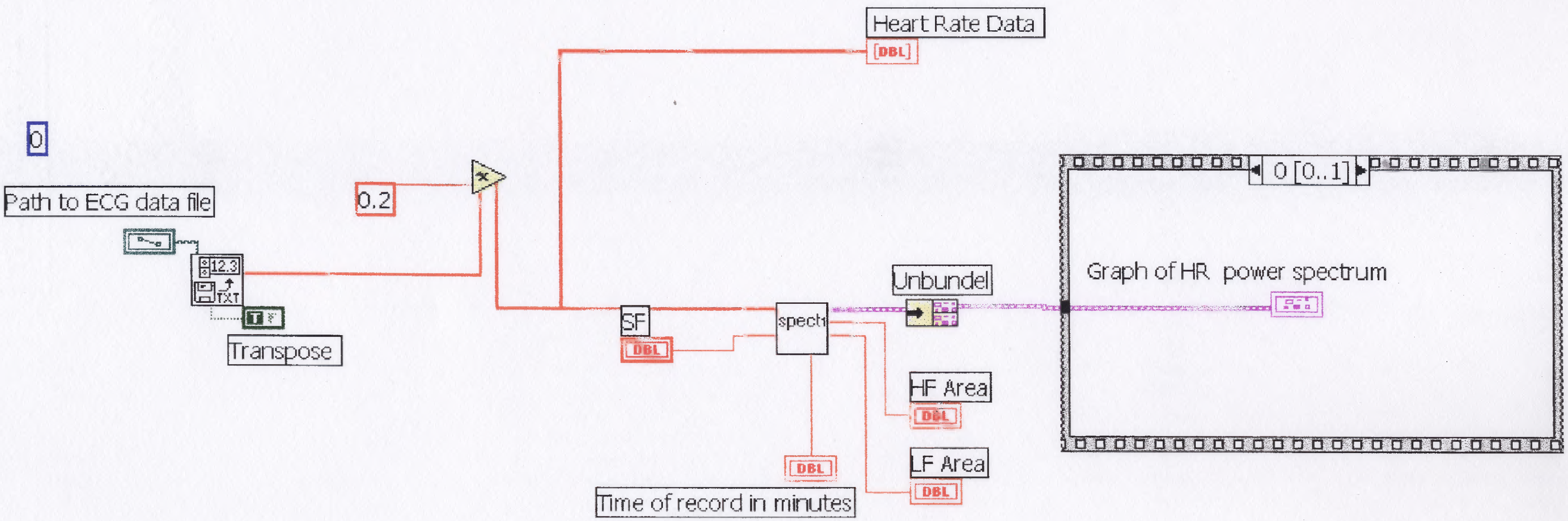
```
cycle1 = Import["d:\c11week824hour.hrm", "Text"];
Needs["Statistics`DataSmoothing`"];
Needs["Statistics`DescriptiveStatistics`"];
, (Part[Part[StringPosition[cycle1, "[HRData]"], 1], 2] + 1)];b = StringToStream[c]; a = ReadList[b, Number];
Close[b]; cycle = {}; cyclea = {}; Do[If[a[[i]] == 9999, 0, cycle = Append[cycle, a[[i]]]], {i, 1, Length[cycleb]}]; cycleb = a;
(****Initialise output variables******)
circl = {-10.0}; circmx = {-10.0}; circmn = {-10.0}; circpd = -10.0; tcircmax \
= -10.0; tcircmin = -10.0; vx1 = -10.0; vn1 = -10.0; vcircmax = -10.0; \
vcircmin = -10.0; tultmax = -10.0;(*test for proper length*)If[
  Length[a] < 12960, Goto[skip]]; cyclea = {};
(****Remove points outside the range 29 - 231*********)
Do[If[a[[i]] > 28 [And] a[[i]] < 232, cyclea = Append[cyclea, a[[i]]]], {i,1, Length[a]}];
cycle = cyclea; l = Length[cycle] - 400;
(**** Statistics`DataSmoothing****)
 circl = N[MovingAverage[cycle, 400]]; circl = Drop[circl, -1];
(*first find the peaks and valleys of the ultradian cycles*)
mx = {0}; mn = {0}; ult[j_] := (a1 = Take[circl, {1 + 800*(j - 1), 1000 + 800*(j - 1)}];
m1 = Max[a1]; n1 = Min[a1]; Do[If[a1[[i]] == m1, mx = Append[mx, i + 1 + 800*(j - 1)]], {i, 1, Length[a1]}];Do[If[a1[[i]] == n1, mn = Append[mn, i + 1 + 800*(j - 1)]], {i, 1,Length[a1]}]);l = Floor[(Length[circl] - 1000)/800];
```

```
Do[ult[j], {j, 1, l}];mx = Drop[mx, 1];
mn = Drop[mn, 1]; mx1 = {mx[[1]]}; Do[If[(mx[[i]] - mx[[i - 1]]) > 500, mx1 =
Append[mx1, mx[[i]]]], {i, 2, Length[mx]}];
mn1 = {mn[[1]]}; Do[If[(mn[[i]] - mn[[i - 1]]) > 500, mn1 = Append[mn1, mn[[i]]]], {i,
2, Length[mn]}];
vx1 = cycle[[mx1]]; vn1 = cycle[[mn1]]; vx2 = circ1[[mx1]]; vn2 = circ1[[mn1]];
(****Peak and valley of circadian cycle*****)
circmx = {0}; circmn = {0}; m1 = Max[circ1];
n1 = Min[circ1]; Do[If[circ1[[i]] == m1, circmx = Append[circmx, i]], {i, 1,
Length[circ1]}]; Do[If[circ1[[i]] == n1, circmn = Append[circmn, i]], {i, 1,
Length[circ1]}]; circmx = Drop[circmx, 1]; circmn = Drop[circmn, 1]; vcircmax =
circ1[[circmx]]; vcircmin = circ1[[circmn]];
(***Find circadian and ultradian periods*****)
circpd = N[(5/3600)*(circmx[[1]] - circmn[[1]])]; circpd = Abs[circpd];
mx2 = Table[0, {Length[mx1] - 1}];
(*<< Statistics`DescriptiveStatistics`*)
Do[mx2[[i - 1]] = (mx1[[i]] - mx1[[i - 1]]), {i, 2, Length[mx1]}];
ultpd = N[(5/3600)*Mean[mx2]];
(****Find acceleration of ultradian waves********)
a1 = mn1[[1]];
If[(mx1[[1]] - mn1[[1]]) > 0, a2 = mx1[[1]], a2 = mx1[[2]]]; If[a2 < a1,
a2 = a1 + 1];
acc = Take[circ1, {a1, a2}];
acc1 = Table[0, {Length[acc]}];
Do[acc1[[i - 1]] = (acc[[i]] - acc[[i - 1]]), {i, 2, Length[acc]}];
ultacc = Max[acc1]; tcircmax = N[(1/720)]*circmx[[1]]; tcircmin =
N[(1/720)]*circmn[[1]]; tultmax = N[(1/720)]*mx1; Label[skip];
output = {circ1, circmx, circmn, circpd, tcircmax, tcircmin, vx1, vn1,vcircmax, vcircmin,
tultmax};Label[skip];ListPlot[cycle, PlotJoined -> True, AxesLabel -> {"Time in
Minutes", "Heart Rate"}, DefaultColor -> RGBColor[1, 1, 1],
PlotStyle -> {RGBColor[1, 1, 1], Thickness[0.001]}, Background -> RGBColor[0.458,
0.458, 0.358], PlotLabel -> "Circadian Plot"] ListPlot[circ1, PlotJoined -> True,
AxesLabel -> {"Time in Minutes", "Heart Rate"}, DefaultColor -> RGBColor[1, 1, 1],
PlotStyle -> {RGBColor[1, 1, 1], Thickness[0.001]},
Background -> RGBColor[0.458, 0.458, 0.358], PlotLabel -> "Circadian Plot"]
circ1;
circmx
circmn
circpd
tcircmax
tcircmin
vx1
vn1
vcircmax
vcircmin
tultmax
```

B.3 Lab View Program

Focused Breathing

This program is a modified version of the original work of Douglas. A Newandee
% Modified by Ujwala. G. Kalambur (Lab view Version 5.1)



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