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Investigation of pathophysiologic trends in Caucasian and Afro-American hypertensives by means of heart rate variability recording during upright tilt-table testing

Jose F. Torrealba
New Jersey Institute of Technology

ABSTRACT

INVESTIGATION OF PATHOPHYSIOLOGIC TRENDS IN CAUCASIAN AND AFRO-AMERICAN HYPERTENSIVES BY MEANS OF HEART RATE VARIABILITY RECORDING DURING UPRIGHT TILT-TABLE TESTING

by

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The incidence of hypertension is more prevalent among the Afro-American population than the Caucasians and there is not a satisfactory explanation for this discrepancy.

Heart Rate Variability (HRV) has been demonstrated to reflect the relative activities of the sympathetic (SMP) and parasympathetic (PSMP) divisions of the autonomic nervous system (ANS).

This study consisted in comparing the HRV, as well as the blood pressure (BP) of four different groups during up-right tilt table testing. The subjects were grouped by age, gender, race and health condition. Analysis in time and frequency domain was applied to the data. In the frequency domain, the LF and HF bands were studied. In the time domain, a new parameter was proposed to analyze the data. As a result, the ratio of the HF area, from the supine to the standing positions, was higher in the hypertensive group than the normotensive one, and the ratio of the LF area was higher in the normotensives than the others. On the other hand, Afro-Americans had a higher LF area ratio than Caucasians and a lower HF area ratio.

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Jose F Torrealba

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Jose F Torrealba

Dr. Peter Engler, Thesis Advisor — Date
Associate Professor of Electrical and Computer Engineering, NJIT

Dr. Joaquim J. Correia, Thesis Co-Advisor — Date
Assistant Professor of Medicine and
Director of Arrhythmia Services, UMDNJ

Dr. Stanley S. Reisman, Committee Member — Date
Professor of Electrical and Computer Engineering, NJIT

Dr. David S. Kristol, Committee Member — Date
Professor of Chemistry and Director of Biomedical
Engineering Program, NJIT

BIOGRAPHICAL SKETCH

Author: Jose F Torrealba

Degree: Master of Science in Electrical Engineering

Date: May 1998

Undergraduate and Graduate Education:

- Master of Science in Electrical Engineering
  New Jersey Institute of Technology, Newark, NJ 1998

- Bachelor of Science in Electrical Engineering
  Universidad de Carabobo, Barbula, Venezuela, 1994

Major: Electrical Engineering

To God
and
my beloved wife
Bassma

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CHAPTER 1

INTRODUCTION

1.1 Objective

The objective of this study is to record and analyze changes in the heart rate, blood pressure and respiration signals from Afro-Americans and Caucasians with and without high blood pressure during a tilt table test. Differences of the heart rhythm may be found among people based on race or even in the same race with high blood pressure and those who do not have high blood pressure.

These differences in heart rate between Afro-Americans and Caucasians with and without high blood pressure may help physicians to improve the prescription of medications to control hypertension.

The incidence of hypertension is more prevalent among the Afro-Americans than the Caucasians and there is no a satisfactory explanation for this discrepancy [12]. Heart rate variability (HRV) has been demonstrated to reflect the relative activities of the sympathetic (SMP) and parasympathetic (PSMP) division of the autonomic nervous system (ANS).

It is hypothesized that the high incidence of hypertension among Afro-Americans may be related to a disorder in the ANS.

1.2 Background Information

Hypertension remains a major cause of stroke, cardiovascular disease and all cause mortality in the adult and particularly, in the elderly populations. Afro-Americans suffer from hypertension more frequently than Caucasians, with higher rates of morbidity and mortality [12].

Over the past few years, technological advances have allowed an improved understanding of the autonomic interactions controlling blood pressure and heart rate variability as well as creation of new tools capable of accurately recording these phenomena.

An interesting issue is whether heart rate variability measured during routine tilt table testing can identify differences between Caucasian and Afro-American subjects with and without hypertension. These differences may ultimately improve the understanding of pathophysiological features in these specifics populations of hypertensives, with a view toward improved prognostic indicators and treatments in those at highest risk of complications.

1.2.1 Autonomic Nervous System

The autonomic nervous system (ANS) is part of the nervous system that controls the visceral functions of the body. Regulation of internal activities such as blood pressure, heart rate, gastrointestinal motility and body temperature, among many others, is performed by the ANS [5]. Autonomic activity is controlled mainly by centers in the spinal cord, brain stem, and hypothalamus [5].

The ANS is made up of two functional divisions: (1) the sympathetic (SMP) and (2) the parasympathetic (PSMP) nervous system. The sympathetic nervous system is generally responsible for creating an increased level of activity in an organism. Anatomically, sympathetic nerves are organized as a two-neuron chain: a preganglionic neuron and a postganglionic neuron [5]. These nerves pass from the spinal cord through the white ramus into one of the sympathetic ganglia before reaching their destination (see figure 1.1). Most postganglionic sympathetic nerve endings secrete norepinepherine, a neurotransmitter that activates excitatory receptors, but in some cases can inhibit certain organs. The sympathetic nervous system is also responsible for the alarm or fight-or-fight response [5].

The parasympathetic nervous system by contrast, generally lowers the activity of an organism, and is associated with a relaxed state. Anatomically, parasympathetic fibers leave the brain through cranial nerves III, V, VII, IX, and X, and the second and third sacral spinal nerves (see figure 1.2). Cranial nerve X is also called the vagus nerve, and since the vagus innervates much of the thorax and abdomen, especially the heart, parasympathetic activity is often called vagal activity. All parasympathetic nerve endings secrete acetylcloline [5].

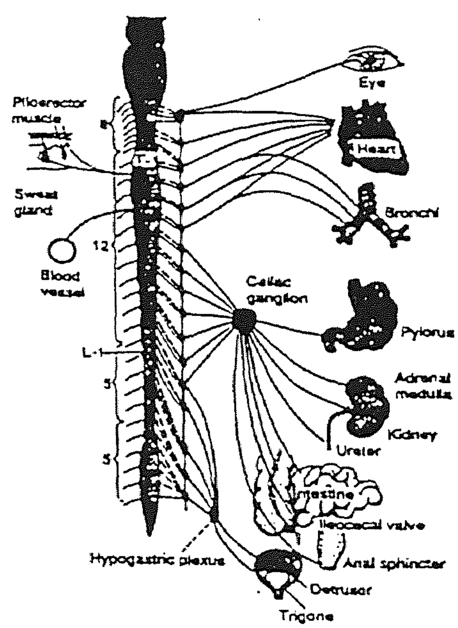


Figure 1.1: The sympathetic nervous system (from Guyton A.C., textbook of medical physiology).

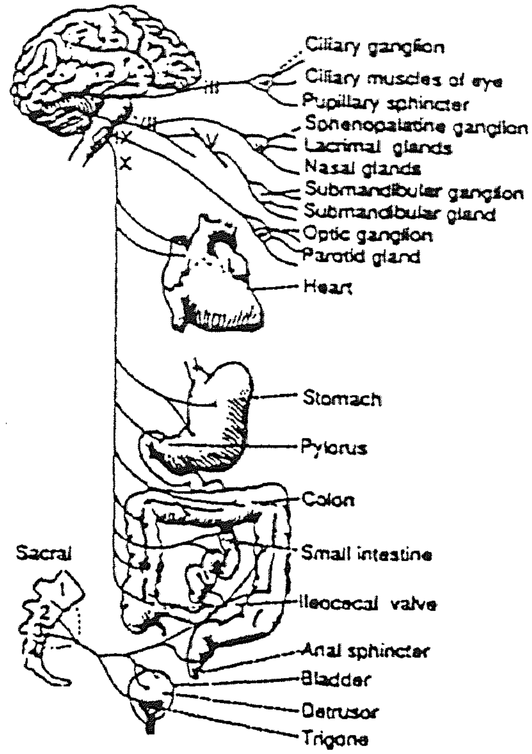


Figure 1.2: The parasympathetic nervous system (from Guyton A.C., textbook of medical physiology).

1.2.2 Heart and the Autonomic Nervous System

The heart is an organ that is often treated in isolation as a mechanical pumping device. However, the autonomic nervous system (ANS) regulates rhythm and contractility of the heart. Although inherent rhythmicity of the heart is generated by a natural pacemaker tissue in the sinoatrial node, continuous beat to beat control of HR is dependent on the relative balance between sympathetic and vagal nerve impulses delivered from the brain to the sinus node [12].

Specifically for the heart, sympathetic fibers terminate at the sinus node pacemaker, conduction system, atria, ventricles, and coronary vessels. The parasympathetic fibers in the vagus nerve terminate at the sinoatrial and atrioventricular nodes, atrial and ventricular musculature, and coronary vessels (see figure 1.3). All blood vessels receive sympathetic fibers and some vessels supplying visceral organs such as the heart also receive parasympathetic fibers [5].

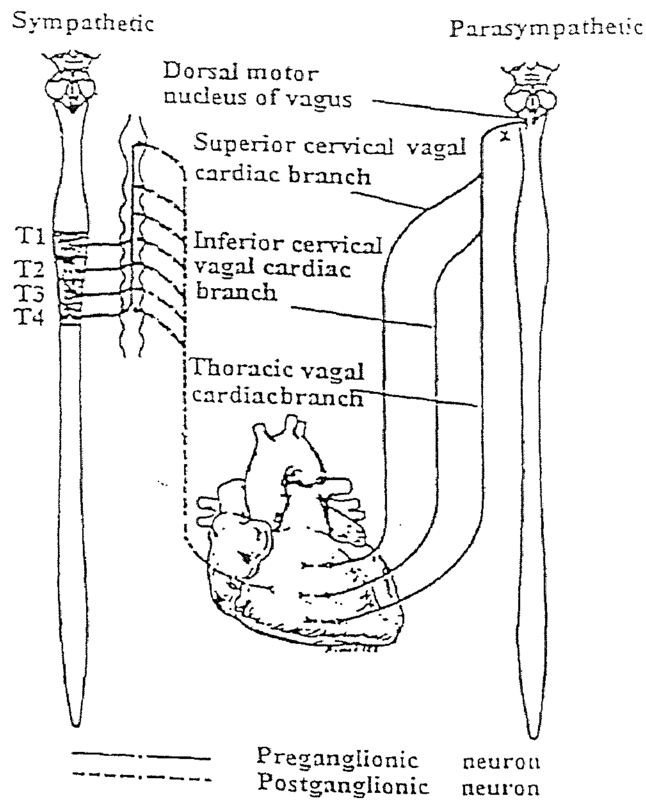


Figure 1.3: Diagram depicting the nerve supply to the heart from both divisions of ANS(from Guyton A.C., textbook of medical physiology).

The ANS characteristically functions as a feedback control system. Although a central command controls overall autonomic behavior, several reflexes provide quick feedback to respond effectively to specific demands on the system. For example, changes in HR due to alterations of BP are dependent upon pressure or stretch receptors, called baroreceptors, located in the carotid sinuses and the aortic arch (see figure 1.4). Baroreceptors and vasomotor reflexes contribute towards maintaining the arterial BP within a tight physiological range so as to meet the changing demands for blood supply by major organs. Baroreflex response is significantly altered during certain disease states.

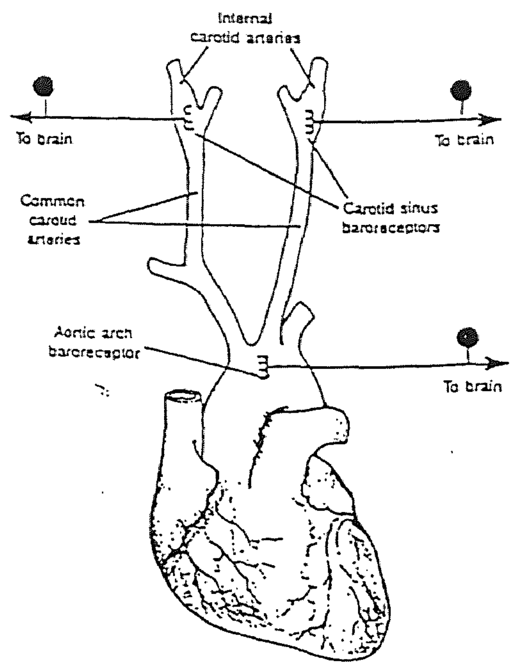


Figure 1.4: Location of arterial baroreceptor (from Guyton A.C., textbook of medical physiology).

Due to the role played by the ANS in regulating all major organs in the body, diagnostic tests to assess the integrity of the ANS and its modulating effects on the heart have been developed. The basic objective of such tests is to subject the ANS to a known stressor that activates a reflex and measure the response of the end organ, namely the heart. The HR response to such stressors as a change of position from supine to standing, deep breathing, valsalva, and lower body negative pressure has emerged as an index of autonomic control [10].

1.2.3 Heart Rate Variability

Traditionally, the effect of the autonomic nervous system on heart rate causes short term fluctuations in the instantaneous heart rate [4]. Studies of these short terms fluctuations are collectively referred to as heart rate variability (HRV) studies. This effect has been investigated through two approaches. First, the average heart rate measured under normal conditions as a reference, and then the average heart rate measured under different drug treatment, like atropine to block the parasympathetic nervous system (PSMP) and propanolol to block the sympathetic nervous system (SMP) [4]. Recently, a second approach has used power spectrum analysis to decompose a biological rhythm such as heart rate variability (HRV).

HRV studies are performed by extracting heart rate information from the ECG monitor by measuring the time between each R wave, referred to as the interbeat interval (IBI), and converting these IBI values into the frequency domain. This result is what is called power spectrum of the HRV.

Power spectral analysis of the HRV is a powerful non-invasive tool for exploring the autonomic nervous system activity. It is well known that the SMP activity increases the heart rate and the PSMP activity decreases it [1]. In the spectrum of short segments of HRV, there are three visible peaks (see figure 1.5): a very low frequency peak (VLF), a low frequency peak (LF), and a high-frequency peak (HF) which has been linked to the respiration, and is called the respiration peak [4]. Table 1.1, shows the frequency range for each peak.

Table 1.1. Frequency range for each peak.

Peak	**Frequency range (Hz)**
VLF	< 0.07
LF	0.07 - 0.15
HF	0.15 - 0.40

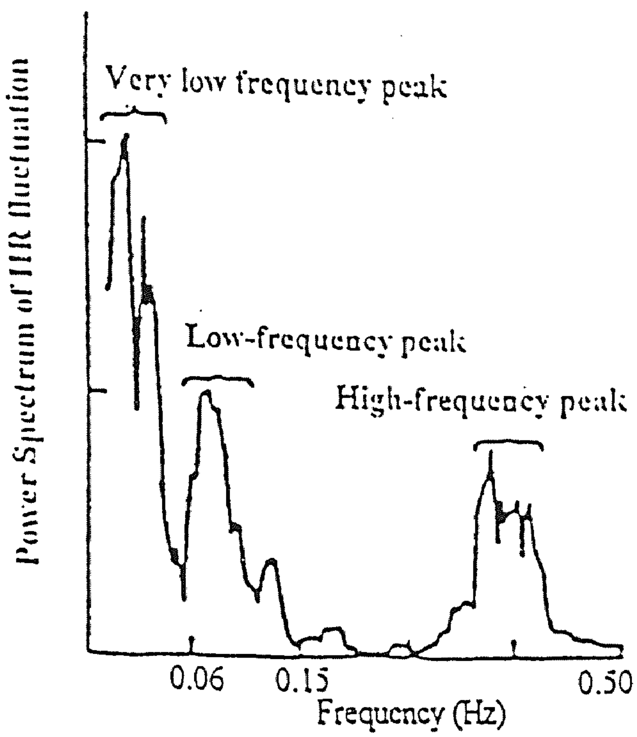


Figure 1.5: Fourier Transform of heart rate fluctuations, indicating verly low frequency, low frequency, and high frequency peaks. (From Akserold, S. et al. Science,1981).

The high frequency band (HF) has been linked with the parasympathetic activity; the greater the area under the HF peak, the more active is the parasympathetic division of the

CNS. The low frequency band (LF) is related to both parasympathetic and sympathetic activities. The VLF has been linked with vasomotor control and/or temperature control [11] but is omitted in this thesis because data was not collected for sufficiently long intervals. The locations of these peaks are reproducible within and across normal control subjects, regardless of the method of frequency analysis. In this project, the power spectrum of the HRV, obtained using HRVIEW (Boston Medical Technologies) software, was used to identify the changes of the PSMP and SMP activities.

1.3 Tilt Table Testing

Several variables, such as the age, posture (supine vs. standing), level of physical conditioning (athlete vs. sedentary), breathing frequency, circadian cycle, and mental state, all influence neurocardiac regulatory mechanisms (see appendix A).

When rising from a supine to a standing position, reflex mechanisms are activated which prevent a fall in blood pressure. These mechanisms modify HRV tone of sympathetic dominance. In figure 1.6, the effects of the tilt table testing can be observed. The figure shows 5 minutes of data from an Afro-American 25 years old. These plots show the results after the subject has been in each position for at least two minutes. Thus, a response to a physiological stress such as standing is an attractive method for evaluating the ANS. It has been demonstrated that the power under the LF peak increases significantly on standing due to baroreceptor mediated efferent sympathetic outflow to the heart and the power under the HF peak decreases on the standing position [1].

Pharmacological interventions are often undertaken to provide insights into the autonomic control of the heart. As an example, when atropine, which inhibits the PSMP activity, was administered to healthy control subjects, the area under the HF peak decreased by 84% in the supine position and by 72% in the standing position [9]. A combination of propanolol and atropine did not produce any different effects in the area under the HF peak from that due to atropine alone. Based on these observations, the LF peak may reflect baroreceptor response to BP fluctuations and a marked increase in the area under the LF peak when standing up from a supine position may then be attributed to increased barorecepetor gain [10].

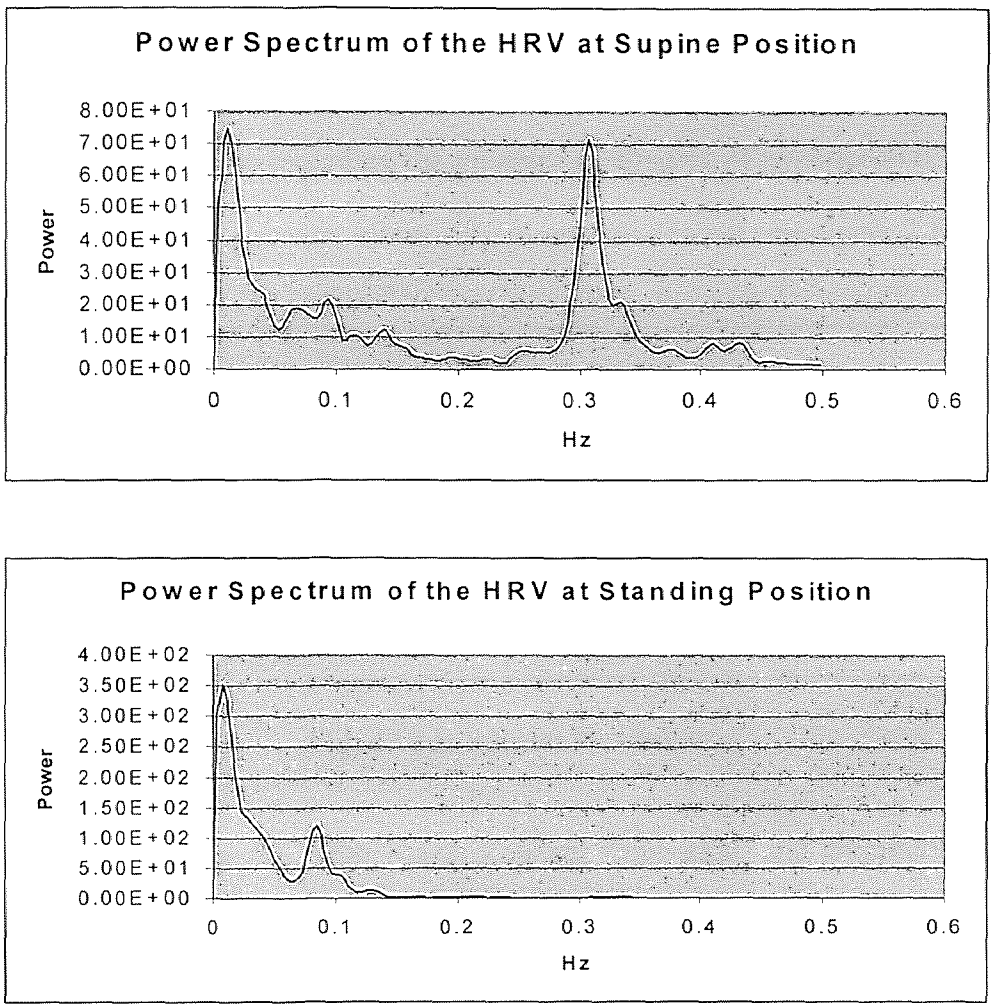


Figure 1.6: Power Spectrum of the HRV at supine and standing positions.

CHAPTER 2

METHODS

2.1 Overview

This thesis was a pilot study of heart rate variability in subjects referred for routine tilt table testing. This study was done in three phases.

1. Subject enrollment. This consisted of willing, non-pregnant adult subjects referred for tilt testing (the exclusion of minors and pregnant subjects is based on different patterns of hypertension in these groups). Four groups of subjects were enrolled on historical information regarding the presence or absence of hypertension, and by race characteristics of Caucasian versus Afro-American descent (see figure 2.1).

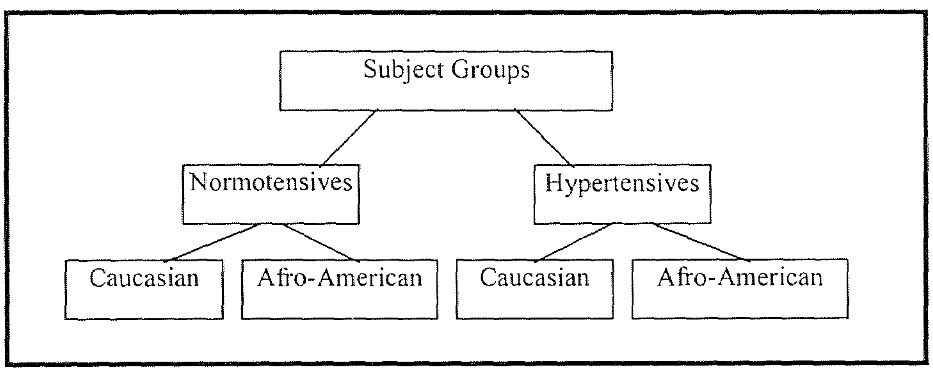


Figure 2.1: Subject distribution.

2. Routine tilt table testing with blood pressure, respiration, and continuous heart rate monitoring/recording was performed to the subjects. The testing protocol consisted of the following steps:

- The subject was resting (supine) for 5 to 10 minutes.
- The subject was tilted 80° degrees (upright) for 15 to 20 minutes.
- The subject was resting (supine) for 5 to 10 minutes again.

3. Analysis of the three signals recorded (blood pressure, respiration and heart rate) was performed using the Boston Medical Technologies HRView software (see appendix B).

2.2 Instrumentation

The basic equipment used during the test consisted of:

- A tilt table automatic (700 series Boston Gear).
- An ECG monitor (HP terminal monitor).
- A blood pressure monitor (Finapres 2300).
- A respiration belt (RSP-01 respiration pneumogram amplifier from Boston Medical Technologies).
- A HRView basic kit (HRView software, PC-LPM-16 data acquisition card, and HRV-A1 BNC adapter).
- IBM compatible computer - Pentium 100 MHz – 16 MB RAM.

2.3 Acquisition of ECG Signal

A monitor terminal HP 78532B from Hewlett Packard was used to monitor the ECG signal. Diagnostic ECG adhesive silver/silver chloride surface electrodes (Medtronic, Haverhill MA) were placed on each subject to collect the ECG data. The positive electrode was placed on the torso rather than on the left lower extremity in order to minimize electromyographic noise. This signal was fed into the PC-LPM-16 data acquisition board.

2.4 Acquisition of the Blood Pressure Signal

Real-time pulse blood pressure data was collected as an analog signal using a Finapres Model 2300 Blood Pressure Monitor (Ohmeda, Englewood CO). Analog data was fed into the PC-LPM-16 data acquisition board. The converted signal was then stored in an IBM-compatible Pentium 100 MHz computer.

The Finapres measures arterial blood pressure in the finger using a method originally devised by Dr. Jan Penaz [10]. The 2300 Finapres monitor provide continuous measurement of finger arterial blood pressure displaying the pressure waveform, digital values of systolic, diastolic, and mean pressure as well as pulse rate. To provide the dynamic response required to accurately measure the arterial waveform, the cuff's pressure servo valve and the pressure transducer are located in the subject interface module at the end of the subject interface cable. A finger cuff containing photoelectronic components for measuring a blood plethysmograph and a bladder for applying pressure to the finger, is wrapped around the subject's finger and connected to the subject interface module (see figure 2.2) [10].

To optimize the Finapres measurements the following steps were followed: (1) A conventional sphyngomanometer blood pressure measurement was done in the other arm, to compare with the ones obtained from the Finapres. (2) The hand should be as relaxed as possible. (3) For the best results, fingers with good circulation were used, since poor circulation would produce low blood pressure values and dampened (rounded) waveforms. (4) Fingers were positioned at the heart level and the instrument adjusted until the Finapres reading was within +/- 20mmHg of the sphyngomanometer reading.

The Finapres instrument is no longer on the market because it failed to produce accurate absolute measurements of blood pressure. In the experiments presented here, the Finapres was employed in the identical manner in each subject. Even though the absolute value may not be reliable, the relative reading between subjects do reflect qualitative variations of BP between these subjects.

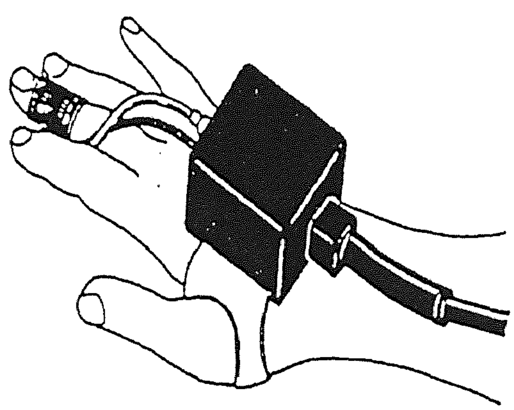


Figure 2.2: Finapres equipment connected to the subject's hand.

2.5 Acquisition of the Respiration Signal

The RSP-01 respiration pneumogram amplifier was used for measuring the respiration rate. The system uses a strain-gauge sensor in an elastic belt placed around subject's chest or abdomen to measure expansion, yielding a measure of respiratory effort. The belt should be fastened tightly enough so that it stretches slightly when the subject's chest/abdomen is at minimum expansion, but no tighter than is necessary.

The best location for placing the belt will vary from subject to subject. It is best to observe the subject, and place the belt around the area whose circumference changes most.

2.6 Data Analysis

The HRView analysis application (HRVANLYS) was used to analyze the data. This application is the basis of the HRView system. Using HRVANLYS, the researcher can graphically display, print, and/or write to disk the following signals.

- Time Domain

    Heart rate (R-R interval or rate).

    Respiration.

    Systolic blood pressure.

    Diastolic blood pressure.

    Average blood pressure.

    Pulse blood pressure.

- Frequency Domain

    - Power spectral density

        Heart rate

        Respiration

        Systolic blood pressure.

        Diastolic blood pressure.

        Average blood pressure.

Pulse blood pressure.

- Transfer function between any two spectra.
- Total power spectral density in the specified band.
- Peak power spectral density in the specified band.
- Frequency at which the peak power spectral density occurs in the specified band.

In this thesis, the data analysis was implemented in two areas. In the time domain, the ratio of the time slopes of the heart rate and the blood pressure signals was calculated. The slope is defined as the rate of change of HR or BP during the interval that the subject's position was changed from supine to standing (80° degrees). (See figure 2.3).

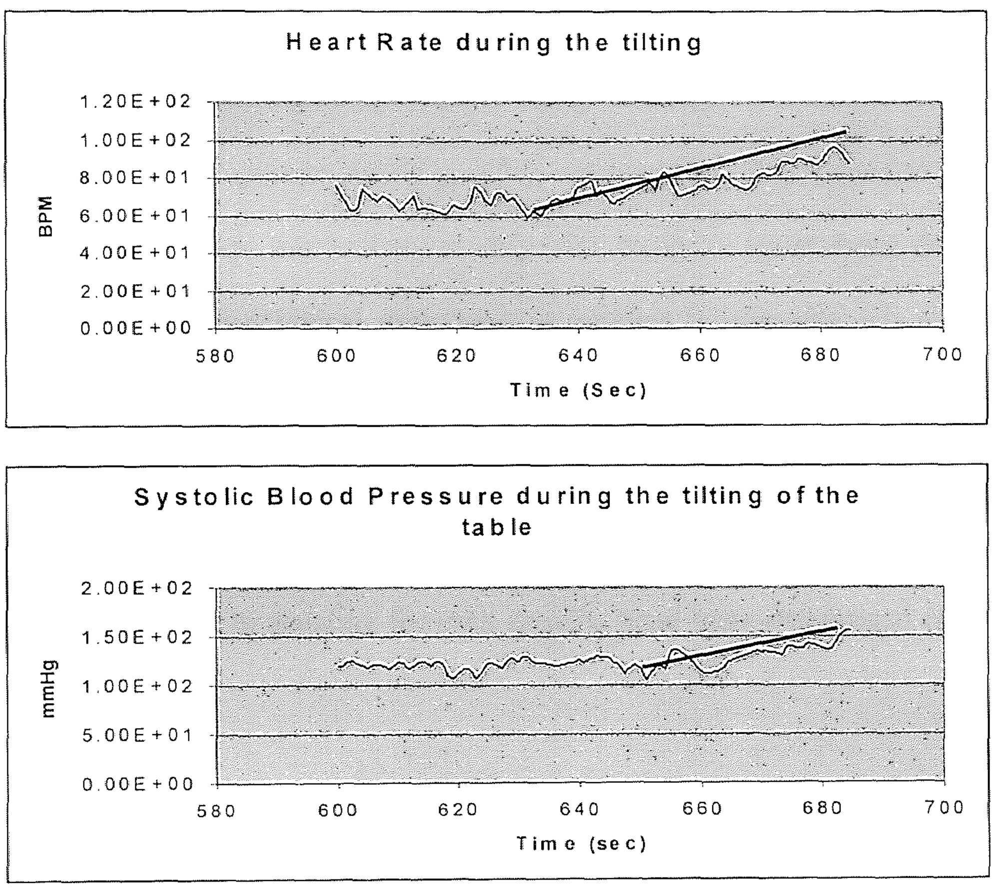


Figure 2.3: Slopes of HR and BP signals during the interval that the subject's position was changed from supine to standing (80°).

The units of the HR slope are "bpm / sec" and the units of the BP slope are "mmHg / sec".

In each signal (HR and BP signals), the minimum and maximum points were calculated during the up-right tilting. Therefore, in order to get the ratio of the slopes, the slope for each signal was determined using these maximum and minimum points and then the ratio was calculated as slope HR over slope BP.

Slope ratio = slope HR signal / slope BP signal. [bpm/mmHg]

Thus, the slope ratio is interpreted as the increase in HR per mmHg increase in BP as the subject is repositioned from the supine to standing positions.

The explanation of looking in this specific variable was given in chapter 1. During a change of posture from supine to standing, reflex mechanisms are activated to prevent a fall in blood pressure. These mechanisms modify HRV to one of sympathetic dominance. Thus, a response to a physiological stress such as standing is attractive as a method for evaluating the ANS. It is hypothesized that it is due to the baroreceptor activity.

In the frequency domain, the total power spectral density for the LF and HF peaks were calculated in the supine and standing positions (see figure 2.4.a). Then, ratios of these values from supine to standing for each specific band were determined (see figure 2.4.b).

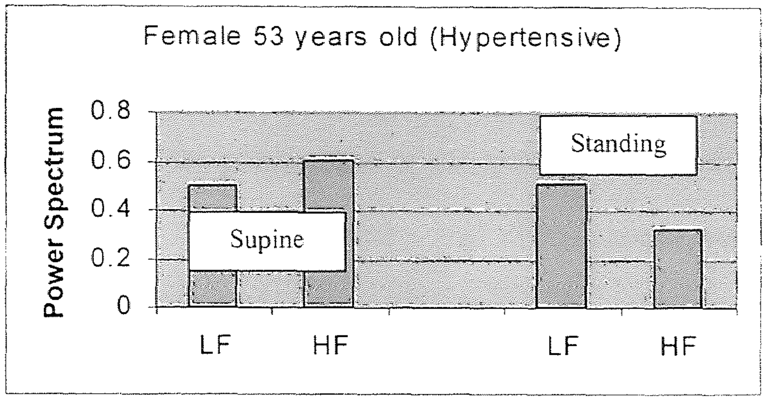


Figure 2.4(a): The LF and HF areas from the supine to the standing positions.

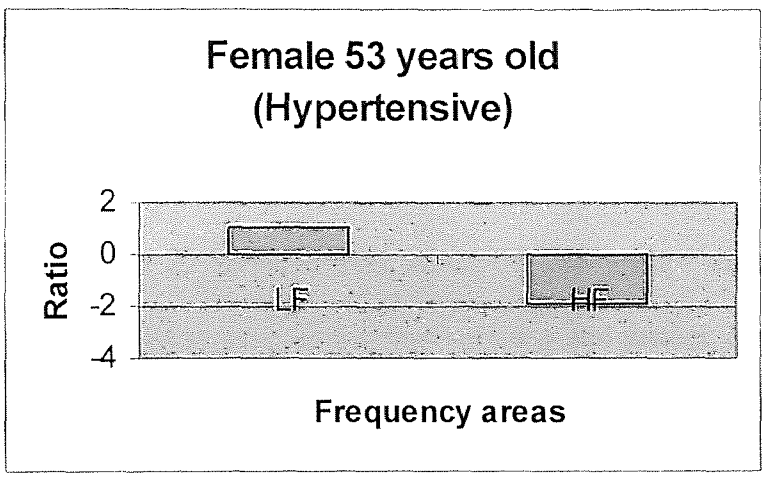


Figure 2.4(b). Ratios of the LF and HF areas (2.4a) from the supine to the standing positions.

In figure 2.4(b), the HF ratio is negative, reflecting the expected observation the PSMP activity is lower in the standing subject than in the supine one. In the LF ratio, the SMP activity is greater in the standing position than in the supine one, therefore the result showed the positive ratio as it was expected.

CHAPTER 3

RESULTS

The following chapter details the progression of the research. The number of subjects were not as many as was expected. There were a total of 20 subjects (see table 3.1). Of these only two were hypertensives; the remaining were normotensives between Caucasians and Afro-americans.

Table 3.1: Classification of the subjects for their conditions and race.

Health Condition/ Race	Normotensives	Hypertensives
Afro-Americans	5	None
Caucasians	13	2

In seeking a pattern, the 20 subjects were classified into groups depending on the race, health condition (hypertensives or normotensives), age and gender. See table 3.2 for the groups' description. Since the number of subjects were not enough, the classification of the subject depended more on the gender and the age.

Table 3.2: Groups description.

Group	Gender	Age	Race	Health Condition
I	Females	> 46	Caucasians	Normotensives and hypertensives.
II	Females	40 – 45	Caucasians	Normotensives and hypertensives.
III	Males	20 – 30	Afro-Americans and Caucasians	Normotensives
IV	Females	25 – 55	Caucasians	Normotensives and hypertensives.

3.1 Hypertensives vs. Normotensives

In this section, Groups I, II and IV were considered.

Group I – Hypertensives vs. Normotensives

There are 2 females over 40 years old. One of them is a sedentary, 53 year old hypertensive under Ditiazem ("Dilacor") treatment and the other lady is a sedentary 48 years old normotensive. Dilacor is a calcium channel blocker drug that doesn't influence the SMP or PSMP activity. Figure 3.1 contrasts the LF and HF frequency areas of the two subjects between supine and standing positions. The effects of tilting can be appreciated based on the changes of the LF and HF areas. One of the data analysis techniques, explained in chapter II, was the ratios of the LF and HF areas in the supine position to the standing. The result of this analysis is shown in figure 3.2.

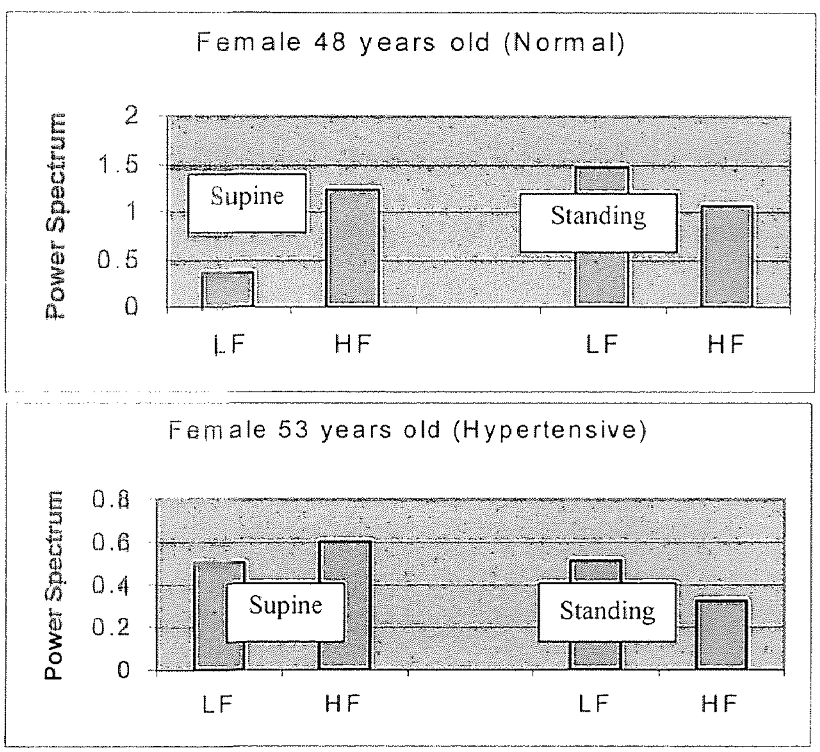


Figure 3.1: The LF and HF areas of the two subjects of group I.

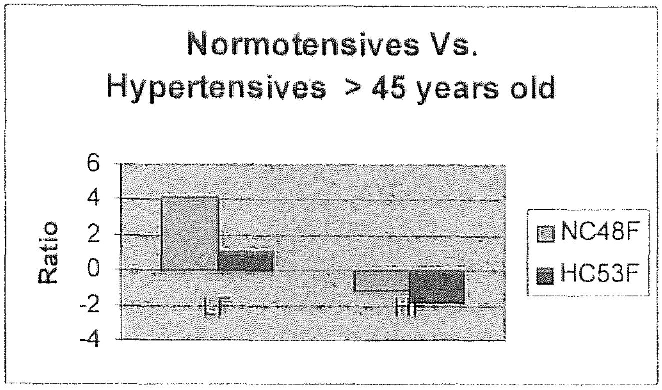


Figure 3.2: Ratio of the LF and HF areas of subjects of group I, from supine to standing positions.

The increase of LF area from supine to standing is more pronounced (5 times greater) in the normal subject than the hypertensive one. The HF area in the hypertensive subject decreased more on a change of posture than in the normotensive one. All these conclusions can be observed in figure 3.2. During tilting, reflex mechanisms are activated which prevent a fall in blood pressure [1]. These mechanisms modify tone of sympathetic dominance and it is believed due to the baroreceptor activity. Therefore, studying the ratio of the slope of the HR and BP signals (see figure 3.3) during the tilting interval suggests that the increase in HR per mmHg increase in BP (remember the units of this parameter) is greater in the hypertensive subject (HC53F) compared to the normal one (NC48F).

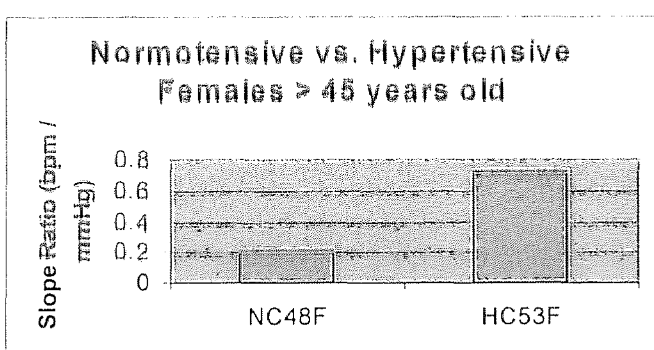


Figure 3.3: The ratio of the slopes of the HR / BP signals from the subjects of the group I, during tilting interval.

Group II – Females, age > 40 yrs old.

There are 3 females between 40-45 years old. One of them is an active person 41 years old, hypertensive under no medications, another lady is a sedentary 44 years old normotensive and the third lady is a sedentary 43 years old normotensive. The description of this group is in table 3.3.

Table 3.3: Subject descriptions of the group II.

AGE	SUBJECT DESCRIPTION	ID CODE
41	Hypertensive - sedentary (not controlled).	HC41F
43	Normotensive – sedentary	NC43F
44	Normotensive – sedentary	NC44F

As it was done with the group I. Figure 3.4a,b, shows LF and HF frequency areas of the three subjects, from supine to standing position. In this figure, the hypertensive subject had her LF and HF values close to each. Contrary as people could expect, the NC43F subject has the LF area higher than HF area in the supine position. It might indicate that the subject was feeling uncomfortable during the supine position or under stress. The values of the ratio of the LF and HF areas between supine and standing positions are shown in figure 3.5. In this figure, the hypertensive subject shows a similar pattern (higher decrement in HF area) as it was observed in the group I. Since the data from the hypertensive subject during the tilting interval was not good, the calculation of the ratio of the slopes of HR/BP signals were done combining the subjects from group I and II (see figure 3.6).

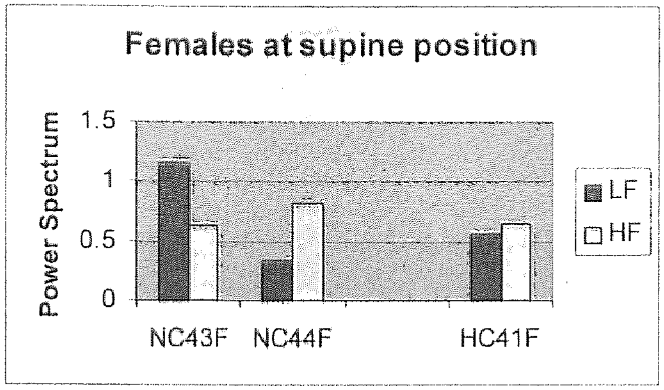


Figure 3.4a: The LF and HF areas of the three subjects in supine position.

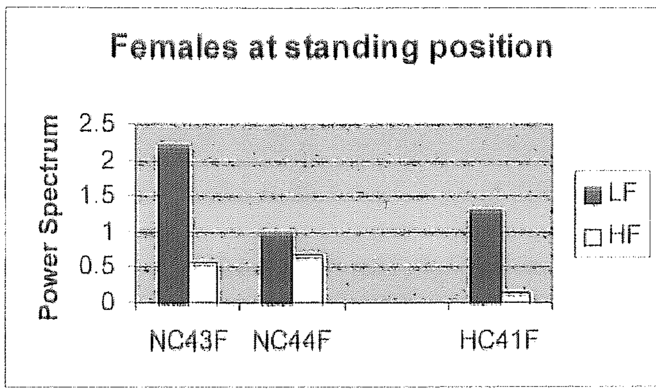


Figure 3.4b: LF, HF frequency areas of the three subjects at standing position.

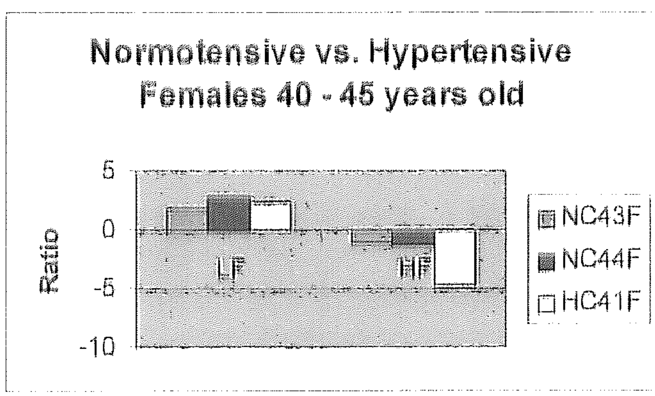


Figure 3.5: Ratio of the LF, and HF areas from the supine to the standing positions.

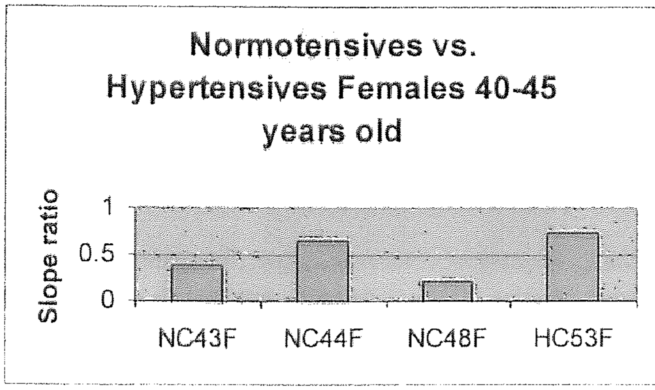
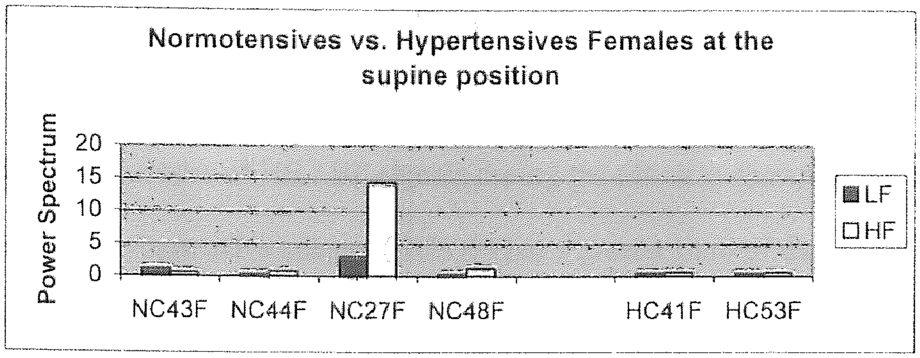


Figure 3.6: Slopes ratio of HR/BP signals of the subjects from group I, II.

The results of group II were similar to those obtained in the first group. The major difference can be observed in the ratio of the HF area. The hypertensive subject demonstrated a dramatic decrease (by a factor of 5:1) in this HF area compared to the normotensive ones, suggesting that the PSMP activity decreases more in the hypertensive subject that in the normotensive one when the subjects are placed in the standing position from the supine position.

Group IV – (groups II and I together)

In this group, all females were considered no matter age or health condition. The subjects from the group II and I were included in this group. A young subject 27 years old is the only new subject observed in this group with respect to the others. The LF and HF areas of this group can be observed in figure 3.7. The ratio of the LF and HF frequency areas of all the females are shown in figure 3.8.



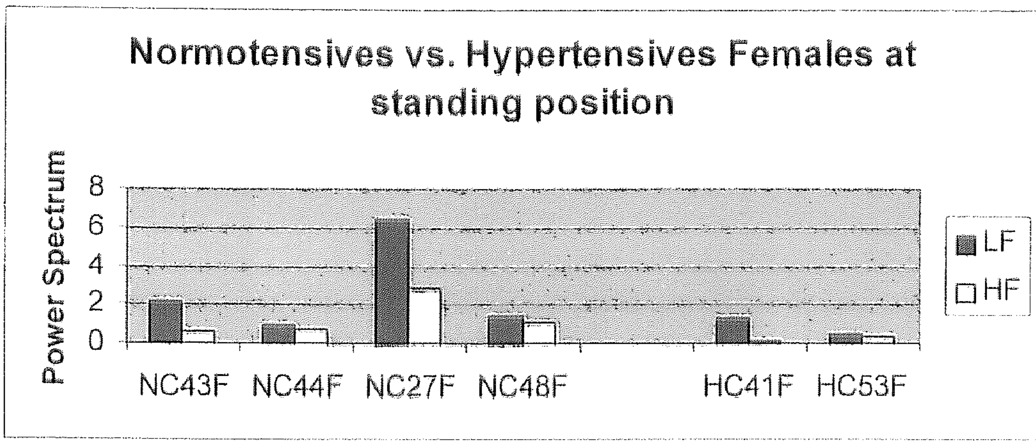


Figure 3.7: The LF and HF areas of the group IV from the supine to the standing positions.

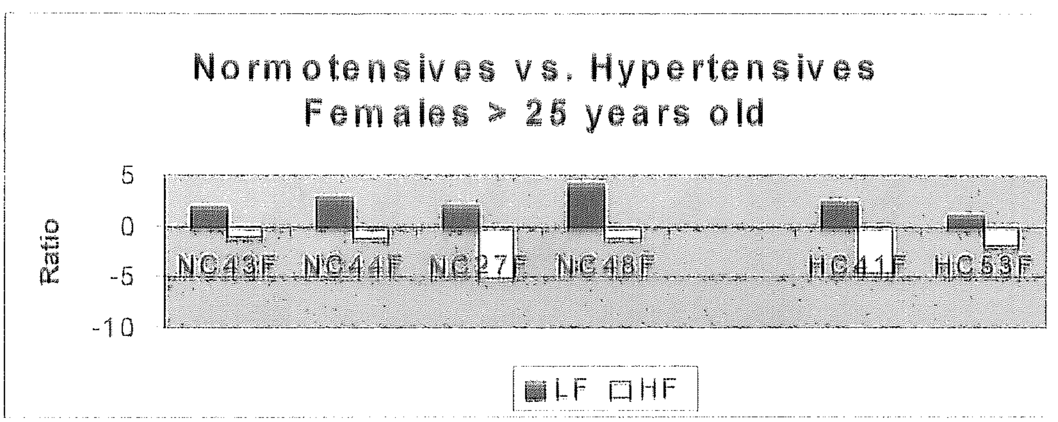


Figure 3.8: Ratio of the LF and HF areas of the group IV from the supine to the standing positions.

In figure 3.8 is very clear to observe if you exclude the young subject that the ratio of the HF area is greater in the hypertensive subjects than the normotensive ones.

The ratio of the slopes of HR / BP signals during the tilting is shown in the figure 3.9. In this figure, the hypertensive subject (HC53F) has a greater ratio of the slopes than the all normotensive ones.

In general, it is important to distinguish the results from these Caucasians females; the inclusion of the young subject may have changed the pattern that it was showing from the other two groups. But, it is important to consider the age and the life style in this case.

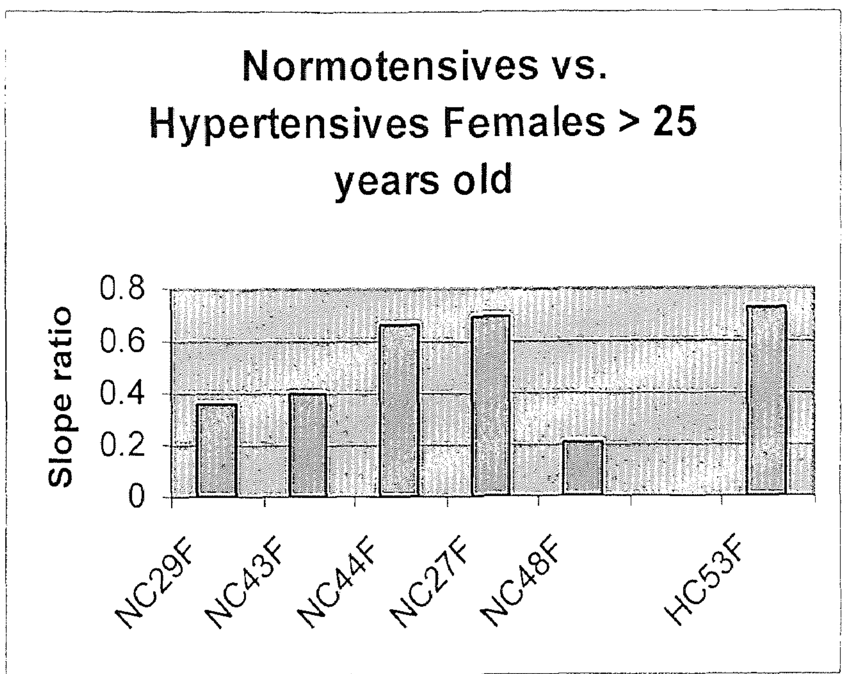


Figure 3.9: Ratio of the slope of HR/BP signals of the subjects of the group IV during tilting interval.

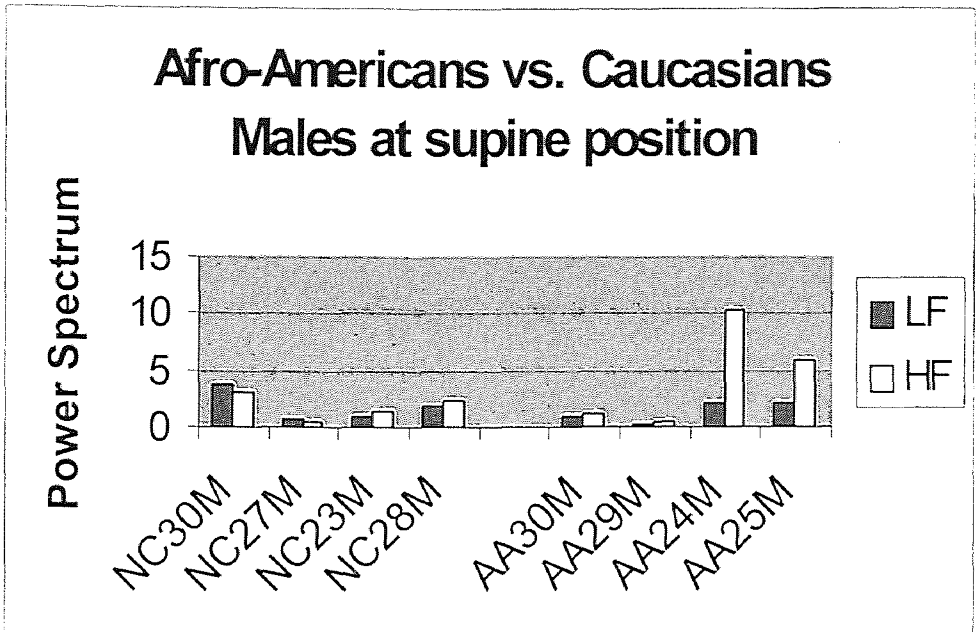
3.2 Afro-Americans vs. Caucasians

In this section, Group III is the only one included. The subjects in this group are young healthy Afro-Americans and Caucasians. There are 8 subjects, 4 Afro-American and 4 Caucasians. The age range is between 20 to 30years old (see table 3.4).

Table 3.4: Subject descriptions of group III.

AGE	SUBJECT DESCRIPTION	ID CODE
30	Caucasian – student	NC30M
27	Caucasian – student	NC27M
23	Caucasian – student	NC23M
28	Caucasian – student	NC28M
30	Afro-American – student	NAA30M
29	Afro-American – student	NAA29M
24	Afro-American – student	NAA24M
25	Afro-American – active (2hrs exercise everyday)	NAA25M

Figure 3.10 shows LF and HF frequency areas of these subjects, from supine to standing position. The ratio of the LF and HF areas from supine to standing is shown in figure 3.11 and the ratio of the slopes of HR / BP signals of these subjects can be observed in the figure 3.12.



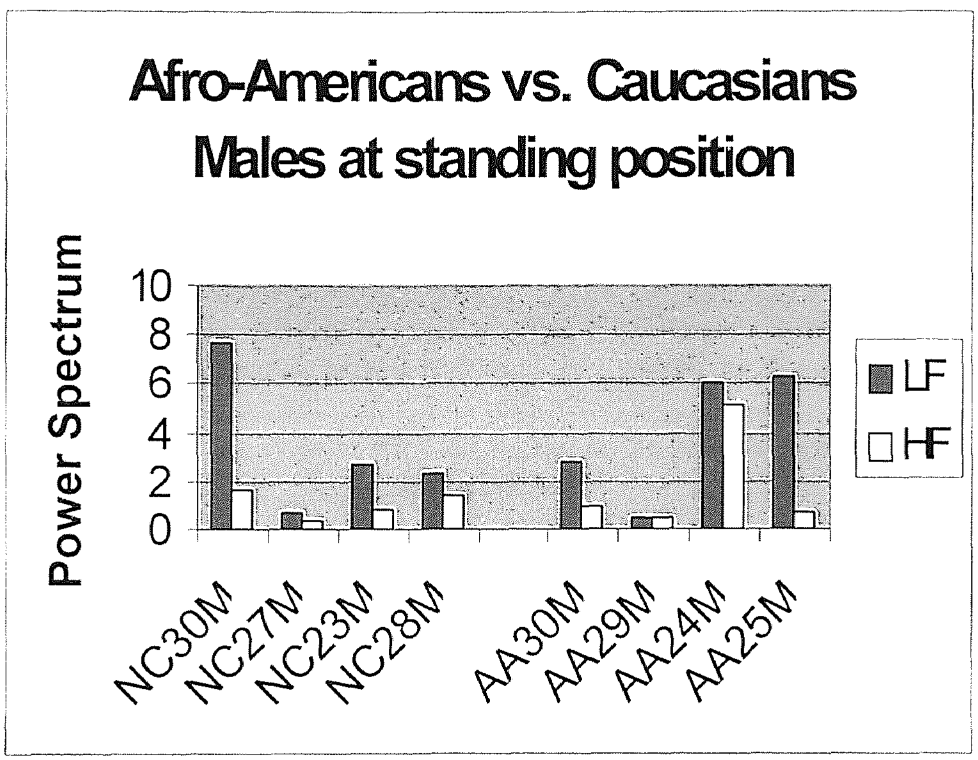


Figure 3.10: The LF and HF areas of subjects of group III, from the supine to the standing positions.

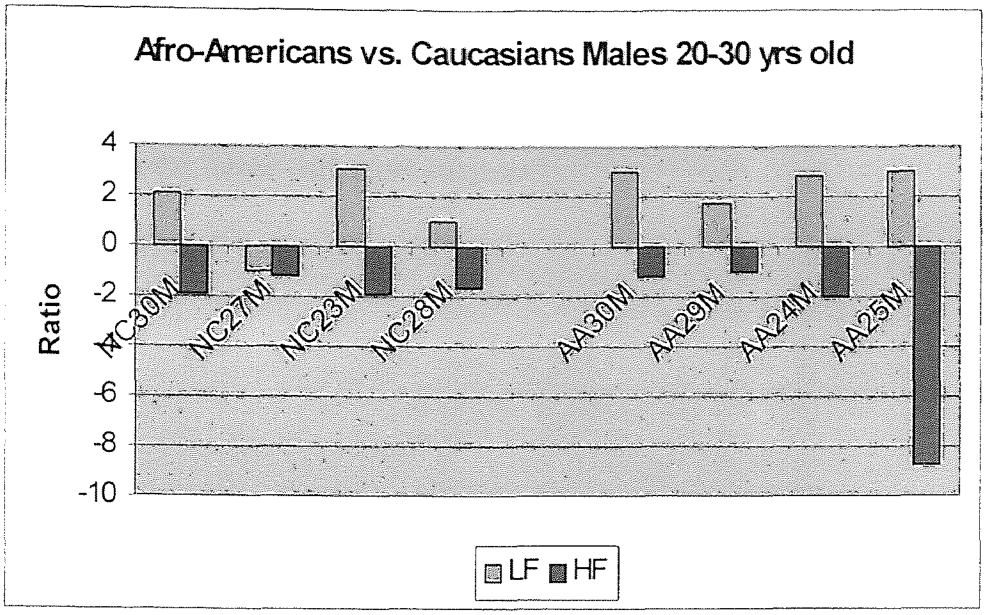


Figure 3.11: Ratio of the LF and HF areas from supine to standing position.

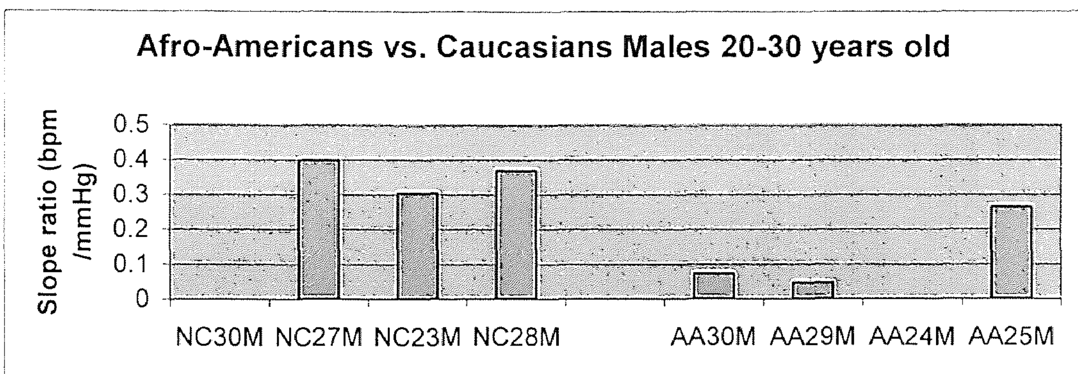


Figure 3.12: Ratio of the slope of HR / BP signals of the subjects from group III during tilting interval.

Since there were so few subjects in this study any inferences need to be validated in the future using a large number of subjects. In figure 3.11, the ratio of the LF area is higher (factor 2:1) in the Afro-Americans group than Caucasians, and there is not a big differences in the ratio of the HF area. The ratio of the slopes of HR / BP signals demonstrates another difference between Afro-Americans and Caucasians. This parameter is higher in the Caucasians group than the Afro-Americans. The ratio of the slopes may suggest that there is a difference in the baroreceptor activity of these two groups. These appear to be a pattern between Afro-Americans and Caucasians but it has to be validated in the future with more subjects.

CHAPTER 4

CONCLUSIONS AND FUTURE STUDIES

Since there were so few subjects in this study, any conclusion has to be validated in the future with a large number of subjects.

A conclusion from the frequency domain analysis could be the following: the ratio of the HF area appears to be higher in the hypertensive group than the normotensive one, and the ratio of the LF area is higher in the normotensives than the others. It may indicate that the SMP activity is being affected drastically due to the disease. In the other hand, Afro-Americans seems to have the ratio of the LF area higher than Caucasians and the ratio of the HF area lower.

From the time domain analysis, the parameter proposed, ratio of the slopes of the HR and BP signals demonstrates another difference between Afro-Americans and Caucasians. This parameter may suggest that there is a difference in the baroreceptor activity. Remember, even though the results may indicate a pattern, they have to be validated.

The present study was just an introduction to the future studies, in terms of looking for differences between Afro-Americans and Caucasians. Improvement of the blood pressure measurement and a larger number of subjects are the essential factors to validate these results.

APPENDIX A

FACTORS INFLUENCING THE POWER SPECTRA OF THE HRV/BPV

Several variables, such as the age, posture (supine vs. standing), level of physical conditioning (trained athlete vs. sedentary), breathing frequency, circadian cycle, and mental state, all influence neurocardiac regulatory mechanisms. A researcher has to be aware of such factors. These factors might have some influence on the HF or LF peak. Some of these factors are summarized below:

Posture

As was mentioned in chapter 1, by changing posture from supine to standing, reflex mechanisms are activated which prevent a fall in blood pressure. These mechanisms modify HRV to one of sympathetic dominance. It is now believed that the power under the LF peak increases significantly on standing due to baroreceptor-mediated efferent sympathetic outflow to the heart.

Exercise

Exercise produces a change in autonomic balance. The response of the ANS to exercise has been investigated using power spectrum of HRV over long periods [46,81-85]. Pagani et al. observed that mild levels of exercise increased the LF component [55]. However, others have noted a decrease in the LF area during steady-state exercise [81-85]. Precise mechanisms for the reduction of LF power during steady-state exercise are not clear. It is uniformly observed that the HF power is depressed during exercise.

Age

Advanced age affects ANS function in general. For HRV, it is known that increasing age results in diminished HRV and a reduced HR response to maneuvers such as standing, valsalva, and to a single deep breath [88]. Aging also produces an increase in peripheral vascular resistance and a decrease in peripheral vascular capacitance [89]. Pagani et al. found that R-R interval variance decreased with increasing age both at rest and during upright tilt [55].

Gender

Mean HR has been found to be higher in women that in men in the awake and sleeping states [91]. However, Arai et al. [83] found that in healthy controls, the power spectrum of HRV essentially demonstrates the same pattern irrespective of gender.

Medications / Drugs

Pharmaceuticals are often used to study sympathovagal balance in humans and animals through selectively augmenting or blocking neurotransmitter function of the ANS. Of particular importance are the drugs that produce B-adrenergic blocking effects (sympatholytic) and anticholinergic (vagolytic) effects.

Mental Stress

A rise in sympathetic activation, as measured by power spectrum of HRV, has been observed during experimental mental stress in the laboratory.

Circadian Variations

It is thought that a circadian pattern pervades human physiological function, including the ANS. Hayano et al [101] examined diurnal variations in the power spectrum of HRV in eight healthy male controls, under controlled laboratory conditions. They observed a greater vagal power in power spectrum of HRV during the mourning hours. The vagal component diminished shortly after a meal.

APPENDIX B

HRVIEW SOFTWARE

Overview and Features

The HRView software is a product that meets the needs of the heart rate variability (HRV) researchers. This software allows HRV researchers to focus on the scientific and medical aspects of research and results by minimizing the time-consuming procedures of HRV measurement. Some of the features of the software are the following:

- HRView provides for the acquisition, calibration, and analysis of up to three signals:

  1) Heart rate.
  2) Blood pressure (Systolic and Diastolic).
  3) Respiration.

- HRView includes facilities for performing and analyzing standard time-domain autonomic function tests, including valsalva, metronomic deep breathing, standing 30/15, and other standard tests that analyze heart rate and blood pressure response to various challenges.
- Processed data (time series and spectral data) are directly available, without the need for the user to perform multiple, time consuming, intermediate steps.
- HRView is highly interactive-during all steps , and data are available for viewing. As parameters are changed (e.g., window length, spectral algorithm), the effects may be observed immediately.

- HRView runs under Microsoft Windows 3.1 and Windows 95, state-of-the-art, multitasking graphical operating system.
- HRView is an open system. All file format descriptions are available. Source code is primarily written using National Instrument's LabView, with, many of the specialized HRV and mathematical routines, such as R-wave detection, systolic an diastolic detection, and so forth, written in C.

HRView System

There are four main programs into the HRView system for four major applications. These are:

1□ HRVCAL, used for equipment calibration.

2□ HRVACQ, used for acquiring HRV data.

3□ HRVEDIT, used for editing HRV data after acquisition.

4□ HRVANLYS, used for analyzing the acquired and edited HRV data.

In order to appreciate how the system works as a whole, let's briefly walk through each of the steps involved in acquiring and analyzing data.

HRVCAL (Calibration)

While respiration and blood pressure are generally measured in liters and mmHg, respectively, the devices that measure these phenomena actually produce a voltage that is read by the HRView system. The calibration procedure establishes the correspondence between the physical phenomena and the voltage output by the measuring device.

HRVACQ (Acquisition)

Acquisition is the process of reading and storing data to the computer. In HRView, a preliminary portion of the analysis (time series generation) is also performed and displayed at acquisition time to help ensure that usable data are being collected.

HRVEDIT (Editing)

During acquisition, HRView automatically detects and marks ECG R waves and blood pressure systole and diastole. After data have been acquired, the user may scroll through the annotated raw data to make sure that these points have been correctly identified. If errors have been made, the user can delete and add annotations as needed.

HRVANLYS (Analysis)

Data that have been acquired (and optionally edited) are used to generate time series, spectra, and other graphs, as well as various statistics. Graphs and statistics may be saved to files readable by statistical and spreadsheet programs.

HRView Hardware Requirements

HRView software runs on any PC-compatible computer capable of running Microsoft Windows. For best performance, the following minimum configuration is recommended:

- 50 MHz 80486 CPU.
- 256 KB RAM cache.
- 8 MB RAM.

- At least 100 MB of free hard drive space.
- Accelerated, Windows-optimized graphics adapter (e.g., ATI, Matrox).
- High-resolution color monitor (1024x768).
- Microsoft Windows 3.1 operating system.
- Compatible data acquisition board (e.g., PC-LPM-16, Lab-PC+).
- Compatible adapter board (BNC-2080).

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