CHANGES IN CW-DOPPLER AORTIC BLOOD FLOW RESPONSES WITH PASSIVE TILTING IN NORMO- AND BORDERLINE HYPERTENSIVE MEN

by

Ray William Morris
Thesis submitted to the faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE IN EDUCATION

in

Health and Physical Education

APPROVED:

William G. Herbert,
Chairman

Don R. Sebolt

Frank C. Gwazdauskas

March, 1989

Blacksburg, Virginia

ACKNOWLEDGEMENTS

I would first like to thank my wife Lori for all of her love and support throughout my years in graduate school. I would also like to thank my parents and family for their support.

I would like to thank Dr. Bill Herbert - without whom this thesis may never have been completed - for all of his help and patience throughout the writing of my thesis. I would also like to thank Dr. Sebolt and Dr. Gwazdauskas for all of their help and guidance in the writing of my thesis.

Next I would like to thank who served with great dedication as a research assistant in the data collection process.

I would also like to thank Dr. Art Pilch whose encouragement and teaching helped me choose the direction in education which I have taken.

I would also like to thank and for their help in constructing my tables and graphs.

Last but not least, I would like to thank all of the faculty and staff of HPER and all of my professors for making my years in graduate school challenging and rewarding and preparing me for life.

TABLE OF CONTENTS

List of Figures

List of Tables

Chapter I

Introduction

The leading causes of death in industrialized societies today are related to degenerative disease of the cardiovascular system (CVD). Each year about one in every 100 American men, 40 years of age or more will develop some symptom of coronary artery disease (CAD); American Heart Association Statistics, 1988, one of the major forms of CVD. As Lamb (1985) has described, CAD is the obstruction of one or more of the arteries that supply oxygen to the heart muscle. In about 60 per cent of CAD cases, the obstruction of blood flow is so great that parts of the heart muscle are unable to function, cardiac output becomes inadequate and the victims may suffer a catastrophic, sudden blockage leading to death immediately or within just a few days.

As well as causing tremendous grief among family members and friends of the victim, CAD costs U.S. industry millions of dollars each year in time lost from work and in terms of health insurance payments. The costs include thousands of dollars in hospitilization, surgery, and drugs for survivors of myocardial infarction and their families.

Today, the health risks associated with CAD development are understood better than ever before. Organizations such as the American Heart Association have funded an expensive research program to discover basic disease mechanisms and explore alternatives for improving clinical management of patients.

Coronary artery disease has been epidemiologically associated, predominantly, with high levels of blood cholesterol, high blood pressure, cigarette smoking, physical inactivity, obesity, and family history of heart disease. Health professionals in modern technologic societies are better prepared than ever before to treat and rehabilitate victims of coronary artery disease.

However, the detection of clinically significant CAD is not always simple and it is an expensive matter. Current non-invasive detection methods having a low or moderate cost are often unreliable. Invasive methods such as radionuclide imaging, thallium perfusion imaging, and coronary angiography are often extremely expensive and often carry a small but definite inherent risk of injury or death for the individual. Even with the advanced medical technology, e.g., thallium scans, angiography, etc., Huntsman, Stewart, Barnes, Franklin, Colocousis, and Hassel (1983) have estimated that 25% of myocardial infarctions (MI) are not possible to diagnose by standard clinical evaluation.

Thus, there is a definite need for new methods by which CAD may be accurately diagnosed without imposing inordinate risk or financial burden on the patient. Recently, Doppler ultrasound has been examined as a possible alternative non-invasive method of diagnosis for CAD. Continuous-wave (CW) Doppler, in particular, may evolve into a valuable tool in the diagnosis of CAD.

Statement of the Problem

Coronary artery disease is one of the most prominent health problems in today's society. The diagnosis of CAD is made by physicians using several different technical methods and interprative skills. A treadmill exercise stress test with electrocardiography (ECG) is a "first-line" approach for screening, monitoring, and evaluating individuals suspected of having CAD. The sensitivity and specificity of the exercise ECG test result will vary markedly according to numerous factors including the patient population studied, the exercise protocol used, the end points to terminate the test, the diagnostic criteria for the exercise ECG test, the monitoring lead system and criteria for "significant" coronary artery lesion. Chung (1983) reported a 54 to 85% prevelance of the abnormal S-T segment response to exercise in symptomatic patients with documented CAD.

Recent technological advances in Doppler ultrasonics have made it possible to measure the function of the left ventricle under conditions of exercise stress. In 1976, Stein and Sabbah presented data indicating that ejection fraction of the left ventricle was an important factor in the detection of coronary disease. Until recently, ejection fraction was determined invasively and the procedure involved cardiac cathertization, vascular injection of a dye solution, and X-ray procedures. Recently, continuous-wave (CW) Doppler ultrasound technology has been applied to measure aortic blood flow characteristics non-invasively. Contemporary research [Huntsman et al.(1983), Bennett et al. (1984), and Sabbah et al. (1986)] suggests that velocity and acceleration derivatives of the Doppler flow provide a valid means of measuring left ventricular function. Furthermore, when ejection period is considered in relation to aortic flow, the resulting integral provides a beat by beat index of stroke volume changes.

The use of CW-Doppler as a screening device in the exercise laboratory setting may be a valuable tool in the diagnosis of CAD. The clinical uses of CW-Doppler systems in exercise testing must await experimental documentation of validity and reliability with human subjects. In particular there are still many important unanswered questions including its use during exercise tests, and which of the measurements recorded by this method provide the most useful information, relative to diagnostically relevant properties of cardiac function.

The purpose of this study was to explore two facets of CW-Doppler utilization. The first related to the question of measurement validity with regard to detection of changes in cardiac stroke volume (SV). The second purpose of the investigation was to determine if there were any significant differences, detectable by CW-Doppler, between normotensive and borderline hypertensive individuals. Specifically, the experiment imposed postural changes in subjects (both normals and borderline hypertensives) under quiet resting conditions and determined the effects on the peak velocity (PkV), peak acceleration (PkA) and the stroke velocity integral (SVI) using the Quinton EXERDOP, a CW-Doppler system especially manufactured for clinical exercise testing.

Significance of the Study

The Quinton EXERDOP, a continuous-wave Doppler ultrasound system, has been designed as a means of non-invasively assessing three primary characteristics of left ventricular function under exercise conditions. These include PkA, PkV, and SVI.

To date, research with this instrument has addressed the validity, reliability, and sensitivity of measurements at rest and during exercise, as well as the clinical relevance of response changes induced by exercise.

It is well documented that certain hemodynamic changes do take place in relation to changes in body posture. When the body is positioned upright, blood is displaced from intrathoracic vascular compartments to more dependent vascular regions in the lower limbs, thus decreasing venous return and SV (Hermiller, Walker, Binkley,, Kidwell, Schaal, Wooley, Stang & Leier, 1984). Conversely, when the body is placed into the supine position, more blood is returned to the intrathoracic compartments causing

SV to increase. Therefore, SVI would be expected to respond similarly to changes in body posture.

In addition to analyzing changes in SVI, PkA, and PkV, induced by postural changes, this investigation examined differences detectable by Doppler between normotensive and borderline hypertensive individuals. Hypertension is the most prevelant of the cardiovascular diseases afflicting an estimated 59 million Americans (American Heart Association Statistics, 1988). Early detection can often be the key to controlling hypertension, thus decreasing an individuals risk for stroke or heart attack. Doppler ultrasound may be a valuable tool in detecting abnormalities in blood flow control in those who are predisposed to hypertension.

Research Hypotheses

Ho1: There is no difference in the continuous-wave Doppler measures of peak acceleration, peak velocity, or stroke velocity integral between normotensive and borderline hypertensive subjects recorded when the body of a quiet resting subject is shifted from supine to +20° head-up and -20° head-down for 15 minutes each.

Ho2: There is no difference in the continuous-wave Doppler measures of peak acceleration, peak velocity, or stroke velocity integral between supine, +20° head-up, and -20° head-down postures regardless of group.

Delimitations

The following major delimitations were inherent in the design of this investigation:

1. The subjects were males ranging in age from 19 to 47 years.
2. The borderline hypertensive subjects had been diagnosed by a physician and were taking no cardiodynamic medications.
3. Peak Velocity, Peak Acceleration, and SVI measures were made for body postures of standing, supine, +20° head-up, and -20° head down.
4. An orientation to the experimental protocol was provided for each subject and was limited to 2-3 practice trials in which the subject was be placed in each of the three postures with the EXERDOP probe positioned at the suprasternal notch.

Limitations

The following limitations are recognized by the investigator:

1. There may be variance in the Exerdop measurements due to placement of the probe by the investigator.
2. Stroke volume was not directly measured.

Basic Assumptions

The following assumptions were made prior to the investigation:

1. The subjects were being truthful when asked to respond to questions about blood pressure diagnosis by a physician, changes in physical activity, sleep and eating habits which might affect the dependent measures of this study.
2. The subjects complied to the requests of the investigator with regards to pre-test activity.
3. The subjects refrained from any strenuous activity on the day of the investigation.
4. The method of measurements for PkA, PkV, and SVI with the EXERDOP was accurate.
5. The changes in stroke volume, indicated in the published research reports, associated with these posture changes did, in fact, occur in the present study.

Definitions and Symbols

1. Borderline Hypertensive- Resting blood pressure $\geq$ 140/90 mmHg as diagnosed by a physician.
2. Continuous-Wave (CW) Doppler- a type of Doppler ultrasound that continually emits ultrasonic waves from the transducer

and receives reflected wave energy at the same transducer almost instantaneously.

3. Ejection Fraction- the volume of blood that is ejected from the left ventricle during systole expressed as a percentage of the total end-diastolic volume of blood in the left ventricle.

4. EXERDOP- name of the CW-Doppler manufactured by Quinton Instruments, a subsidiary of the A.H. Robbins Co., which is specifically designed for clinical exercise testing.

5. Frank- Starling Mechanism- mechanism by which stroke volume is augmented up to a certain degree, by increases in end-diastolic filling volume.

6. Peak Acceleration (PkA)- the first derivative of Peak Velocity which is actually the peak slope of the blood flow being ejected into the ascending aorta during systole. Measured from the time of ejection onset to the time of peak ejection. Measured in $m \cdot sec^{-2}$.

7. Peak Velocity (PkV)- the peak speed at which blood is ejected into the ascending aorta during systole. Measured in $m \cdot sec^{-1}$.

8. Stroke Volume (SV)- The volume of blood pumped out of the ventricles with each beat ($ml \cdot bt^{-1}$).

9. Systolic Velocity Integral (SVI)- stroke distance measured in centimeters. The area under the velocity x time curve during systole.

Chapter II

Literature Review

INTRODUCTION

The left ventricle is perhaps the most critical pumping chamber of the heart. Continuous-wave (CW) Doppler ultrasound has been designed as a means of non-invasively assessing three primary characteristics of left ventricular function: peak velocity (PkV), peak acceleration (PkA), and systolic velocity integral (SVI). As yet, no studies have demonstrated whether the CW-Doppler response of SVI is in fact altered by induced changes in stroke volume (SV) as is purported to be the case. The first section of this chapter will review ventricular ejection dynamics in man. Both animal studies and human studies will be reviewed. The second section of this chapter will review literature concerning ultrasonic assessment of ventricular dynamics. Pulsed-wave (PW) Doppler studies will be reviewed as well as CW Doppler studies. The third section of this chapter will review the effects of orthostatic stress on hemodynamics in man. Specifically, studies involving tilting responses and responses to lower body pressure (both positive and negative) will be evaluated. The fourth section of this chapter will review the differences in hemodynamic responses (specifically blood pressure) to different stimuli between normal and hypertensive subjects.

Ventricular Ejection Dynamics in Man

ANIMAL STUDIES

Rushmer (1964) stated that there needed to be a more accurate way of discriminating between healthy individuals and those with CAD than was possible through assessment of cardiac output alone. Studying dogs, he hypothesized that acceleration imparted to the impulse of blood leaving the ventricles during the cardiac cycle was directly linked to the amount of force which the ventricle was capable of generating. These findings led him to speculate that differences in cardiac function between human subjects could be determined by examining responses for peak aortic blood flow velocity (PkV) and/or blood flow acceleration (PkA).

Noble, Trenchard, and Gus (1966) used an electromagnetic flowmeter to study maximum acceleration from the left ventricle in dogs. Intracoronary injections of calcium gluconate and isopropylnorepinephrine resulted in large increases in maximum acceleration, whereas the cardiac stroke volume remained unchanged. When the anterior descending branch of the left coronary artery was temporarily occluded, the reduction of maximum acceleration was much greater than the reduction in peak flow or stroke volume. Alterations in posture of the dogs hardly affected maximum acceleration but there were marked changes in stroke volume (SV). When the dogs went from a sitting position to a prone position, SV increased by approximately 30% after 10 heart beats. When the dogs went from a standing (four legs) position to an upright position (hind legs) SV decreased by approximately 30% after 10 heart beats. They concluded that maximum acceleration was sensitive to changes induced in left ventricular muscle but insensitive to changes in left ventricular end diastolic volume (EDV).

Stein and Sabbah (1976a) suggested that aortic blood flow responses arriving from ventricular ejection were valuable in assessing left ventricular performance. Studying dogs, they measured left ventricular and aortic pressures using a catheter-tip probe and aortic flow was measured with an electromagnetic flow transducer. The investigators intervened to both augment and to reduce myocardial contractility. They reported that the peak rate of change of power was linearly related to the peak rate of change of aortic flow (r=0.99) in response to both augmentation and reduction of contractility. Also they noted that the rate of change of power indicated an acceleration of energy expended upon the production of useful work by the left ventricle during ejection, and that it was likely that the acceleration of energy expenditure might be a useful expression.

There has been considerable debate over which measurable response characteristic most accurately reflects the contractile state of the myocardium. Lambert, Wilmer, Nichols, and Pepine (1982) compared 24 indicies of ventricular contractile state in anesthetized open chested dogs using an electromagnetic flowmeter and cathetization. They reported the most sensitive index to be the ejection rate of change of power at peak tension; this was reportedly the factor most independent of ventricular preload and afterload. Peak aortic blood acceleration was the ninth most sensitive, while peak aortic blood flow was the thirteenth most sensitive index. The SV ranked 22nd out of 24. Time tension index (SBP x HR/100) was the least sensitive of the indicies being highly dependent on preload and afterload.

Sabbah, Przybylski, Albert, and Stein (1987) studied 24 anesthetized dogs to determine which of PkV, PkA, SV or left ventricular ejection fraction (LVEF) was the best indicator of overall left ventricular performance. They produced different levels of myocardial ischemia by occluding various levels of the left anterior descending and circumflex coronary arteries. The PkV and PkA were measured with CW Doppler, LVEF was measured angiographically and SV was calculated as the ratio of cardiac output to heart rate (HR). Cardiac output was measured with the thermodilution technique. Sabbah et al. (1987) calculated the percent change during ischemia of each variable relative to control. The correlation coefficients between the percent of ischemic mass at risk and PkA and PkV were r=0.88 and r=0.77

respectively. The correlation coefficient between percent ischemic mass at risk and LVEF was r=0.84 and ischemic mass at risk vs. SV was r=0.17. When ischemic mass at risk was <20%, none of the indicies changed significantly. They concluded that PkA was the most sensitive index for the detection of the extent of ischemic mass at risk.

HUMAN STUDIES

Bennett, Else, Miller, Sutton, Miller, and Noble (1974) used a catheter tip to measure changes in velocity and acceleration in 12 CAD patients. They reported that three patients with chest pain but normal functional capacity had a PkA of 15 $m \cdot sec^{-2}$ and a PkV of 60 $cm \cdot sec^{-1}$. Four patients with definite CAD had PkA of 7.5-11 $m \cdot sec^{-2}$ and PkV of 32-58 $cm \cdot sec^{-1}$. Five patients with severe CAD (low ejection fraction) had a PkA below 8.5 $m \cdot sec^{-2}$ and PkV below 41 $cm \cdot sec^{-1}$. Because of the small number of subjects the investigators were unable to establish norms for these measurements. Also, they reported that PkV may be more difficult to determine in individuals with CAD or individuals with a prolapsed valve due to some residual blood flow at the end of diastole which confounds the starting point.

Jewitt, Gabe, Mills, Maurer, Thomas, and Shillingford (1974) also measured PkV and PkA in 24 CAD patients using a catheter tip velocity probe. They reported that patients with PkV below 400

$cm \cdot sec^{-1}$ and PkA below 7.0 $cm \cdot sec^{-2}$ did not have a high survival rate. They concluded that PkV and PkA may have value in pre- and postoperative assessment of patients with angina before and after coronary artery surgery.

Stein and Sabbah (1976b) using a catheter tip probe measured aortic and left ventricular pressures in 22 patients with angina during cardiac catheterization. They reported that in normal patients (normal ejection fraction and normal velocity of circumferential fiber shortening in the presence of a normal end-diastolic volume index) the ejection rate of change of power was $25 \pm 2 \times 10^8$ dyne $cm \cdot sec^{-1}$. In patients with a low ejection fraction and low velocity of circumferential fiber shortening, the ejection rate of change of power was $11 \pm 1 \times 10^8$ dyne $cm \cdot sec^{-1}$. There was a correlation of $r=0.95$ between ejection rate of change of power and change of flow. They concluded that the ejection rate of change of power was a valid index of left ventricular function that was relatively independent of alterations in preload and afterload.

Ultrasound Assessment of Ventricular Dynamics

PULSED-DOPPLER STUDIES

Loepky, Greene, Hoekenga, Caprihan, and Luft (1981) determined that Pulsed-wave (PW) Doppler was an accurate means of estimating SV and cardiac output at rest and during steady-state exercise in both supine and upright positions. They reported that by determining the diameter of the ascending aorta by M-mode echocardiography at rest, beat-by-beat SV can be estimated from the velocity wave forms generated by a PW-Doppler system. They reported that mean supine resting SV was 111 $ml \cdot bt^{-1}$ and mean upright resting SV was 76 $ml \cdot bt^{-1}$. During supine exercise, the mean SV value was 112 $ml \cdot bt^{-1}$ and during upright exercise the mean SV value was 92 $ml \cdot bt^{-1}$.

Elkayam, Gardin, Berkley, Hughes, and Henry (1983) compared the hemodynamic changes after vasodilator treatment to changes in PW-Doppler aortic blood flow measurements. The relationship between the absolute values and percent changes of invasively measured systemic vascular resistance (SVR) and SV and Doppler measured Peak flow velocity (PFV), left ventricular ejection time (ET) and flow velocity integral (FVI) were all evaluated. They reported a correlation of r=0.88 between percent change in Doppler aortic FVI and SV. The SV had correlations with PFV and ET of r=0.75 and r=0.70, respectively. The investigators concluded that Doppler aortic blood flow measurements were useful in the assessment of changes in SVR and SV after vasodilator therapy.

Huntsman, Stewart, Franklin, Colocousis, and Hessel (1983) stressed the importance of developing a non-invasive instrument capable of assessing ventricular function. They used a PW Doppler system to measure aortic diameter and a CW Doppler system to obtain aortic blood velocity. They reported Doppler ultrasound was a useful tool in determining cardiac output in most patients. They compared cardiac output measured by Doppler with cardiac output values measured through thermodilution on acute post-MI patients in intensive care. There was a correlation of r=.83, thus demonstrating a validity coefficient sufficiently high to consider use of the Doppler for monitoring cardiac output changes in critical care settings.

Gardin, Debestani, Matin, Allfie, Russell, and Henry (1984) studied 10 normal subjects to establish the intraobserver, interobserver, and day-to-day variability in PW Doppler aortic blood flow velocity measurements. Measurements were obtained from the suprasternal notch on two different days. Intraobserver variability for ejection time, PkV, and FVI ranged from 1.9 ± 1.8 to 3.2 ± 2.9%. Intraobserver variability was higher for PkA (7.9 ± 6.6%). Interobserver variability ranged from 3.5 ± 2.2% to 5.4 ± 3.4% for PkV, ejection time, and FVI but was significantly higher for PkA (17 ± 9%). Day-to-day variability also was higher for PkA than for the other measurements. They concluded that a change in PkV, ejection time, or FVI of more than 13% on serial recordings performed and recorded by the same observer would be expected to reflect a true hemodynamic change.

Shaw, Johnson, Voyles, and Greene (1985) reported PW Doppler measurements of cardiac output and stroke volume taken during submaximal and peak exercise were reproducible and that they were consistent with reported invasive techniques at various workloads. Also they reported that both PkV and average velocity increased with corresponding increases in workload.

CONTINUOUS WAVE DOPPLER STUDIES

Bennett, Barclay, Davis, Mannering, and Mehta (1984) used a CW Doppler system to measure ascending aortic blood velocity and acceleration. They obtained from the velocity signal a noninvasive measure of SV and cardiac output by combining the Doppler system with M-mode echocardiography. When lower body pressure was applied to subjects in a 30° head-up tilt position, end-diastolic diameter (EDD) increased by 9% which led to an increase in SV of 33% and a 32% increase in cardiac output while there was little effect on acceleration. Maximum acceleration increased 29.2% when dobutamine was infused while there was only a minimal increase in SV. The investigators concluded that CW Doppler was a useful tool in noninvasive monitoring of both inotropic and Starling functions.

Khaja, Sabbah, Brymer, Albert, Goldstein, and Stein (1986) were able to identify global left ventricular dysfunction caused by ischemia by measuring PkA. They reported that global left ventricular performance could be assessed before, during, and immediately after blood occlusion of the coronary artery during coronary angioplasty using CW Doppler (EXERDOP).

Sabbah, Khaja, Brymer, McFarland, Albert, Snyder, Goldstein, and Stein (1986) used a CW Doppler system to measure PkA and PkV in patients undergoing diagnostic left heart cathetization. They reported that patients with ejection fraction of > 60% had PkA of 19 ± 5 $m \cdot sec^{-2}$. In patients with ejection fraction of 41-60%, PkA was 12 ± 2 $m \cdot sec^{-2}$, and in patients with ejection fraction < 40% PkA was 8 ± 2 $m \cdot sec^{-2}$. They concluded that PkA could by used to differentiate between patients with normal and abnormal left ventricular function.

Teague, Corn, Sharma, Prasad, Burow, Voyles, and Thadani (1987) reported that change in PkA and PkV measured by CW-Doppler from rest to peak ejection was as useful as the change in ejection fraction for diagnosing patients with significant CAD. They compared the change in PkA and PkV during exercise with the change in radionuclide ejection fraction. They studied 73 male patients during graded supine bicycle exercise prior to cathertization. Eighteen of the patients had normal or insignificant diseased coronary arteries (< 50% stenosis) and 55 patients had significant disease (> 70% stenosis). In comparing the significantly diseased patients' diagnostic thresholds for change in ejection fraction from rest to peak exertion with percentage change in PkA and PkV the nuclide angiogram had sensitivity/specificity of 0.85/0.78 while corresponding values for acceleration and velocity were 0.90/0.88 and 0.83/0.91 respectively.

Effects of Orthostatic Stress on Hemodynamics in Man

TILTING RESPONSES

Changes in body posture redistribute the flow of the blood. The supine position, in comparison with the upright position, brings about greater venous return due to less resistance against gravity. The greater the venous return causes an increased end-diastolic volume which in turn creates a greater stretch on the ventricle thus causing an increase in ventricular preload which leads to a longer contraction. This phenomenon is known as the Frank-Starling mechanism.

Abel and Waldhausen (1966) studied the influence of posture and passive tilting on venous return and cardiac output in dogs. SV was maximal in the prone position, decreasing 16.3% with sitting and 5.4% with standing although cardiac output did increase in these postures. Head-down tilting (20°) significantly increased SV (21%) and cardiac output (8.1%) in the anesthetized animal but resulted in insignificant changes (SV= +1.42%, Cardiac output= +9%) in the unanesthetized animal. Head-up tilt (20°) on anesthetized animals resulted in a 13% decrease in SV and an 8.4% decrease in cardiac output. In the unanesthetized animal, head-up tilt (20°) decreased SV by 5.2% and cardiac output by 5.8%. In all posutres and tilt positions, measurements were taken at 1 minute and 5 minutes and averaged.

Sibbald, Nigel, Paterson, Holliday, and Baskerville (1979) reported that the Trendelenburg position (15-20° of head-down tilt) resulted in increased preload of both ventricles, slightly increased cardiac output, and decreased systemic vascular resistance in normotensive patients.

Katkov, Chestukhin, Lapteva, Yakoleva, Mikhailov, Zybin, and Uthin (1979) examined central and cerebral hemodynamic effects of -20° head-down tilt over a 3 hour period in six healthy test volunteers. They reported that cardiac output started to increase after 15 minutes, which was primarily associated with a distinct increase in SV. Over the first 15 minutes, SV increased by an average of 20 $ml \cdot bt^{-1}$ but by the third hour it was back within 10 $ml \cdot bt^{-1}$ of resting supine values.

Nixon, Murray, Leonard, Mitchell, and Blomquist (1982) used m-mode echocardiography to compare left ventricular measurements during supine rest to measurements made after a head-down tilt of -5° was implemented for 90 minutes on 12 healthy young men. They reported a 23% increase in end-diastolic volume, a 35% increase in stroke volume, and a 10% increase in ejection fraction. Heart rate (HR) decreased by 5 $bts \cdot min^{-1}$. The mean velocity of circumferential fiber shortening was unchanged. They concluded that all the echocardiographic measurements other than velocity of circumferential fiber shortening, which is an index of contractile state, were significantly altered by large changes in preload.

Lollgen, Gebhardt, Beier, Hordinsky, Borger, Sarrasch, and Klein (1984) studied central hemodynamics during -6° head-down tilt lasting 2 hours in eight healthy males. HR decreased insignificantly by 3-7%, cardiac output remained constant, and SV increased by 8-10% though significance could not be established. End-systolic and end-diastolic diameters or volumes tended to increase, but significance could not be established. It is possible that the small sample size contributed to the non-significant results.

Hermiller, Walker, Binkley, Kidwell, Schaal, Wooley, Stang, and Leier (1984) studied changes in the electrophysiologic properties of the heart brought about by upright posture. By using a catheter, they measured the electrophysiologic effects of going from a supine position to an upright position (80° elevation for 15 to 20 minutes). They reported a significantly shorter cardiac cycle, shorter refractory periods, and increased plasma catecholamines after changing body position from supine to upright. Systolic blood pressure was reduced initially but diastolic blood pressure was unchanged.

Jennings, Seaworth, Howell, Tripp, and Goodyear (1985) placed eight healthy subjects into -10°, -30°, -60°, and -90° head-down tilt positions after 5 minutes of supine rest. At least 15 minutes of supine rest between each position was given each subject to allow the cardiovascular system to return to baseline. Blood pressure and two-dimensional echocardiograms were recorded at supine baseline and immediately after inversion. The only significant change that they reported was an increase in diastolic blood pressure at the -60° position. They reported no significant effect on left ventricular EDV, SV, cardiac output or systolic blood pressure. Again, the small sample size may have contributed to the non-significant findings. Also, in contrast to studies which reported significant changes in SV, EDV, and cardiac output, Jennings et al. (1985) took measurements immediately after inversion.

Knitelius and Stegemann (1987) studied the immediate (5 min) effect on heart volume of -6° head-down tilt in nine healthy subjects. Heart volumes were determined by X-ray. After 5 minutes of head-down tilt, cardiac volumes had increased significantly (+5.2%). These results indicate that head down tilt leads to immediate (within 5 minutes) increases in heart volumes.

Tomaselli, Kenney, Frey, and Hoffler (1987) studied the cardiovascular effects of 6° head down tilt for 1 hour. They reported an immediate fluid shift from the legs to the thorax. SV increased during the first minute and leveled off. A gradual decrease in SV significantly below baseline was observed beginning at minute 15. The HR decreased significantly for the first 2 minutes and reached its lowest point at minute 10. The HR gradually increased beginning in minute 15. Cardiac output increased slightly at minute 1 but was significantly lower than baseline after 60 minutes due to the low SV. The mean stroke ejection rate increased during minute 1 but dropped to 255 $\text{ml} \cdot \text{sec}^{-1}$ by minute 60, which was significantly lower than the baseline measurement of 280 $\text{ml} \cdot \text{sec}^{-1}$.

Katkov, Chestukhin, Kakurin, Babin, and Nikolaenko (1987) administered a 60-70° head-up tilt test to 26 healthy males. In the head-up position for 20 minutes cardiac index decreased on the average of 1.38 $l \cdot min^{-1}$ (32%). Stroke index diminished by 45% and HR increased on the average of 17 $bt \cdot min^{-1}$.

LOWER BODY NEGATIVE PRESSURE and LOWER BODY POSITIVE PRESSURE

Nixon et al. (1982) investigating the effects of lower body negative pressure (LBNP) at -40 mmHG on left ventricular responses reported a 28% decrease in EDV, a 21% decrease in end systolic volume, and a 33% decrease in SV. LBNP was accompanied by a minor increase in HR.

Similarly, Katkov et al. (1987) exposed their subjects to LBNP in the range of -30 to -60 mmHg. They reported decreases in cardiac output and SV of 24% and 36% at -30 mmHg and 32% and 52% at -60 mmHg respectively.

Bennett, et al. (1984) applied lower body positive pressure (LBPP) in the range of +10 to +15 mmHg to six healthy subjects. The treatment caused a systematic increase in preload as indicated by a 9% increase in EDD which increased SV by a maximum of 33% and cardiac output by 32%. The investigators noted that it may not be necessary to use LBPP within the clinical setting because unpublished observations had shown similar responses produced by simple postural changes.

Differences in Hemodynamic Responses to Various Treatments between Normal and Hypertensive Subjects

Katkov and Chestukhin (1980) studied the effects of head-up and head-down tilts at 10°, 30°, and 75 ° for 5 minutes at each angle on the blood pressure and oxygenation in different cardiovascular compartments of 10 healthy male subjects. Direct blood pressure was measured via cathetization in the upper bulb of the internal jugular vein, right atrium, coronary sinus, pulmonary artery, left ventricle, femoral artery and vein, and artery and vein of the foot. In the head-up position, pressure in the upper bulb of the jugular vein varied independently from the pressure in the right atrium which became negative; transpulmonary gradient of the venous pressure (mean pressure in the pulmonary artery minus end-diastolic pressure in the left ventricle) increased; pressure in the leg artery always increased more than in the leg vein, the increase being proportional to the angle of tilt. Systolic pressure dropped in the head-up position. In the head-down position, pressure in the upper bulb of the jugular vein increased, depending on the height of the blood column from the right atrium to the point of measurement; pressure in the cardiac cavities and pulmonary artery tended to increase, decreased in leg vessels, and was approximately zero in the foot artery and vein at 75°. Systolic pressure remained unchanged at -10° and -30° and tended to increase at 75°.

Bonde-Petersen, Christensen, Henriksen, Nielsen, Nielsen, Norsk, Rowell, Sadamoto, Sjogaard, Skagen, and Suzuki(1980) investigated the effects of various gravitational stresses on the cardiovascular system of normal subjects. They reported cardiac output after the first hour of head out of water immersion and -5° bedrest to be increased above that at +5° and basal values but after two hours basal values were reached. During head out of water immersion forearm blood flow immediately increased from 20 to 40-60 ml/min paralleled by a decrease in forearm vascular resistance. During -5° bedrest similar values were gradually obtained after 6 hours, while +5° had no effect on forearm blood flow or forearm vascular resistance. They also reported that lowering the arm below heart level while in the supine position decreased flow and increased resistance. This reflex was not present when LBNP was applied.

Lynch, Long, Thomas, Malinow, and Katcher (1981) examined the effects of talking on the blood pressure of hypertensive and normotensive subjects. Thirty hypertensive subjects and fifteen normotensive subjects were studied. For each subject there were 4 minutes of silent resting, 2 minutes of talking, followed by 2 minutes of silence. Blood pressure was measured by an automatic device (Dinamap 845) at one minute intervals for 8 consecutive minutes. Systolic, diastolic, mean arterial pressure (MAP) and heart rate for all subjects were significantly higher during the talking phase than during the quiet phase. There was a statistically significant mean difference for systolic, diastolic, and MAP between the normotensive and hypertensive group at each of the 8 minutes. There was no significant difference between normotensive and hypertensive subjects for HR at any of the 8-minute recordings. In general, subjects with higher resting baseline pressures tended to show greater increases during talking than did those with lower pressures. In some hypertensive individuals BP increased 25-40% within 30 seconds after the initiation of talking.

London, Levenson, Safar, Simon, Guerin, and Payen (1983) investigated the effects of head-down tilt in 29 normal and 29 sustained hypertensive subjects. They studied central and forearm arterial and venous hemodynamics, arterial baroreflex sensitivity, plasma renin activity and catecholamines in the supine position and after -10° head-down tilt. The treatment had no significant effect on BP, HR, or baroreflex sensitivity in either group. Head-down tilt induced a similar increase in cardiopulmonary blood volume in controls and hypertensives, whereas the increase in central venous pressure, cardiac output, and forearm blood flow was higher in the hypertensives. Forearm venous tone was unaffected in hypertensives but decreased in the control group. Both groups experienced a similar decrease in plasma renin activity and plasma catecholamines. The authors concluded that the higher increase in cardiac output and local flow observed in hypertensives during the treatment is probably due to a higher change in central venous pressure related to a decrease in venous distensiblity.

Goldman, Tarr, Burton, Pinchuk, and Kappler (1985) examined the effects of oscillating inversion of systemic blood pressure, pulse, intraocular pressure, and central retinal arterial pressure in 20 healthy subjects. The subjects were trained to operate the gravity oscillator. They oscillated for 15 minutes with each cycle (from upright to completely inverted and back to upright) taking at least 6 seconds. At 5, 10, and 15 minutes the systemic BP, pulse rate, intraocular pressure, and central retinal arterial pressure were measured while the subject was inverted. Both SBP and DBP decreased on inversion. BP was significantly lower at each successive recording. Pulse rate decreased significantly at the 5 minute and 10 minute measurement periods. Both systolic and diastolic central retinal pressure increased on inversion. Intraocular pressure also increased on inversion.

Klatz, Goldman, Pinchuk, and Tarr (1985) studied the effects of gravity inversion on hypertensive subjects. Ten borderline hypertensive patients with a mean resting blood pressure of 142/88 mmHG were inverted -90° for 3 minutes. Blood pressure was measured at 45 seconds and 3 minutes of inversion. Arterial BP increased from 142/88 to 180/108 mmHG. Central retinal arterial pressure rose from 53/31 mmHG to 108/62 mmHG and intraocular pressure rose from 17 mmHG to 31 mmHG. Pulse rate increased from 80 ± 4 to 106 ± 6.5 bpm. All of these increases were statistically significant.

Differences in hemodynamic function between normals and hypertensives have also been thoroughly documented. It is not known what effects postural changes in combination with borderline hypertension might have on CW-Doppler measurements of aortic blood flow.

Summary

Current methods for non-invasively assessing left ventricular performance are often expensive, physically stressful, and unreliable. Early researchers realized that acceleration imparted to the blood leaving the left ventricle was directly related to the capacity for ventricular force and power development. These investigators demonstrated that peak velocity and acceleration differences at the ascending aorta might be capable of distinguishing between those individuals with ventricular dysfunction and those without.

Research involving continuous wave and pulsed wave systems has indicated that Doppler ultrasound is a useful tool in measuring stroke volume (SV), cardiac output, velocity of blood flow, and acceleration of blood flow non-invasively. The validity and reliability of the Doppler system has been demonstrated by many investigators.

In order to determine if the Doppler measurement of systolic velocity integral (SVI) is a sensitive indicator of SV, a means of selectively inducing SV changes might be evaluated. Several studies involving the hemodynamic effects of head-down tilt and head-up tilt have been inconclusive. These differences are due to inconsistencies in methodology. It is possible to produce measurable alterations in SV in this manner with the proper degree of tilt and the proper amount of treatment time.

Chapter III

Journal Manuscript

Introduction

Cardiovascular diseases constitute the leading cause of death in the United States. The most prevelant form of these diseases is hypertension. In 1988, an estimated 59 million Americans were afflicted by hypertension.[3] However, relative to mortality, coronary artery disease (CAD) is the single most devastating disease in the United States.[3] There is a definite need for methods by which hypertension and CAD may be accurately diagnosed without bringing extensive physical risk or financial burden on the individual. Early detection of hypertension can be most important in preventive medical approaches to controlling the effects of both CAD and stroke in our society. Current procedures and equipment are limited in their ability to detect hypertension at an early stage. Recently, continuous-wave (CW) Doppler ultrasound has been examined as a non-invasive means of assessing left ventricular function.[4,6,7,8,11,18] Previous investigations have demonstrated that, of the measurements made by CW Doppler, peak acceleration (PkA) was the most sensitive to inotropic state while peak velocity (PkV) and in particular systolic velocity integral (SVI) were more sensitive to volumetric loading conditions affecting the left ventricle.[7,16] Substantiating this point, Elkayam, Gardin, Berkley, Hughes, &

Henry[7] reported a high correlation (r = 0.88) between stroke volume (SV) and flow velocity integral (FVI).

The purposes of this investigation were to: (1) impose a postural stress test on both normotensive (NTN) and borderline hypertensive (B-HTN) subjects to evaluate the effects on Doppler measures of aortic peak acceleration (PkA), peak velocity (PkV), and systolic velocity integral (SVI) and; (2) to determine whether NTNs and B-HTNs respond differently to such postural stress in terms of the CW Doppler responses.

Methods

SUBJECTS

Thirty-nine male adults, ages 19-47 yrs., from the faculty, staff and student body of Virginia Polytechnic Institute and State University were volunteers for this study. One group of 20 (19 white, 1 black) was apparently healthy, not taking any prescriptive medications. Each had blood pressure, as verified by quiet resting measurement of $\leq$ 140/90 mmHg, reproduced on separate days in the supine posture. The other 19 (17 white, 2 black) subjects had been previously diagnosed by a physician as having borderline hypertension ($\geq$ 140/90mmHg) but were on no prescriptive medications.

PROCEDURES

The study was conducted in a quiet, controlled environment. Each subject was asked to stand erect, quietly for 3 minutes before the CW Doppler measurements of PkA, PkV, and SVI were taken by a skilled technician continuously for 1 minute from the suprasternal notch using a Quinton EXERDOP (Quinton Instruments, Seattle, WA.). The angle at which the probe was held was determined by the auditory signal generated by the instrument; the intensity and "crispness" of the tones was proportional to the reception of ultrasonic waves being reflected. Under these measurement conditions, it was assumed that the angle of interrogation between signal emission and aortic flow was always less than 20°. The internal consistency correlation coefficients for Doppler measurements were high, ranging from $r = 0.78$ to $r = 0.98$ thus demonstrating response consistency within the segment of the one minute measurement period.

Next, the subject was positioned on a padded tilt table in the supine position where he remained at rest for 15 minutes, before Doppler measurements were recorded for 1 minute from the suprasternal notch. Data were sub-divided into three 20-second blocks so that internal consistency coefficients could be computed for each Doppler measure. Separation of data blocks was achieved with the aid of the EXERDOP's micro computer software. This was done by the investigator utilizing a foot pedal.

Momentary depression of the foot pedal switch affected signal interuption for this "block" averaging procedure. Immediately following the Doppler recordings, blood pressure (BP) and heart rate (HR) were measured using an electronic blood pressure system (Critikon Dinamap 845XT/XT-IEC).

The subject was then shifted passively to a +20° head-up position, the time required to effect the shifts being controlled at less than 5 seconds throughout. The subject remained in this position for 15 minutes. The CW-Doppler measurements were recorded for 1 minute after the subject had maintained the new posture for 15 minutes; BP and HR were taken immediately following the recording of the Doppler responses. Next, the subject was returned to the supine position for 15 minutes to re-establish baseline responses. Finally, the subject was passively shifted to the -20° head-down position where he remained for 15 minutes before final measurements were taken.

DATA ANALYSIS

Statistical analysis included a two-way repeated measures ANOVA employed to determine interactions across groups and postures for each dependent measure of PkA, PkV, SVI, HR, systolic blood pressure (SBP), and diastolic blood pressure (DBP). A dependent t-test procedure was also used to determine if supine Doppler responses were affected by the order or number of postural trials. Statistical significance was determined at the P < .05 level.

Results

The descriptive statistics for both groups are summarized in Table 1. The groups were similar in age, predicted body fat content, and body mass index but significantly different for systolic and diastolic blood pressure (P<.05), as well as for weight, and height (P<.05).

Place table 1 about here.

Changes in the responses after exposure to the sequence of acute postural challenge are presented in Table 2 for both groups. Responses for the Doppler measures of PkA, PkV, and SVI were not significantly different (P<.05) between the first and second supine positions, despite the fact that a postural stress

Table 1. Descriptive data for normotensive and borderline hypertensive subject groups

Group	Resting BP (mmHg) SBP		DBP		Age (yr)		Wt (kg)		Ht (cm)		BF (%)		BMI (Wt/Ht^2)	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
NTN	117.0	9.5	66.0	5.8	26.8	6.3	79.1	10.1	175.5	7.3	11.3	3.6	25.8	2.9
BDL-HTN	139.0	17.4	84.0	13.3	25.2	6.1	91.2	14.2	182.0	6.8	13.5	5.1	27.2	3.7

Abbreviations: NTN=normotensive; BDL-HTN=borderline hypertensive; SBP=systolic blood pressure; DBP=diastolic blood pressure; Wt=bodyweight; Ht=height; BF=bodyfat; BMI=body mass index.

Predicted from skinfold measurements (Jackson and Pollock, 1978).
Values shown are means and standard deviations.

condition of +20° head-up tilt was interposed. The mean for Doppler responses of the NTN group tended to be slightly higher than the means for the B-HTN group, regardless of posture.

The change in SVI for the B-HTN group was significantly lower (P<.05) upon exposure to the supine posture follwoing standing. The B-HTN group also showed significantly (P<.05) less change in PkA, PkV, and SVI upon exposures to the final two postural challenges, i.e., supine and -20° head-down tilt. The only significant (P<.05) interaction effect was that for the SVI response (F = 3.65, df = 4). The greatest mean difference occurred when the subjects were shifted from standing to a supine posture. The mean SVI for the NTN group increased by 34% as a result of this postural shift as compared to a lesser mean increase of 15% in the B-HTN group. This interaction is illustrated in Figure 1.

Place Table 2 about here.

Table 2. Effects of postural stress on CW Doppler measurements in resting men.

Measurement	STD		SUP1		+20°		SUP2		-20°	
			Posture							
PKA ($m \cdot sec^{-2}$)	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE

NTN	15.2	.76	18.0	1.62	14.7	.75	17.3*	1.19	15.3*	.82
BDL-HTN	13.7	.75	14.9	.84	13.0	.79	14.2*	.73	12.5*	.75
PKV ($m \cdot sec^{-1}$)										

NTN	.64	3.19	.73	3.46	.65	2.65	.71*	3.02	.66*	.04
BDL-HTN	.62	3.13	.65	3.67	.58	3.56	.62*	3.16	.53*	.58
SVI (cm)										

NTN	8.0	.55	10.7*	.58	8.7	.53	10.4*	.57	10.1*	.69
BDL-HTN	7.9	.51	8.9*	.57	7.5	.49	8.6*	.58	7.8*	.58

Abbreviations: STD=standing; SUP1=supine 1; +20°=20° head-up; SUP2=supine 2; -20°=20° head-down; NTN=normotensive; BDL-HTN=borderline hypertensive.

*$t>2.37$, $df=37$, $p<.05$

Values shown are means and standard errors.

Place Figure 1 about here.

The mean values for systolic and diastolic blood pressure of the B-HTN group were significantly ($P<.05$) higher than the blood pressures of the NTN group, regardless of posture. In addition, the mean HR for the B-HTN group was significantly higher than that of the NTN group in the standing position but not in the other postures. Table 3 summarizes the effects of each posture on HR and BP responses for both groups.

Place Table 3 about here.

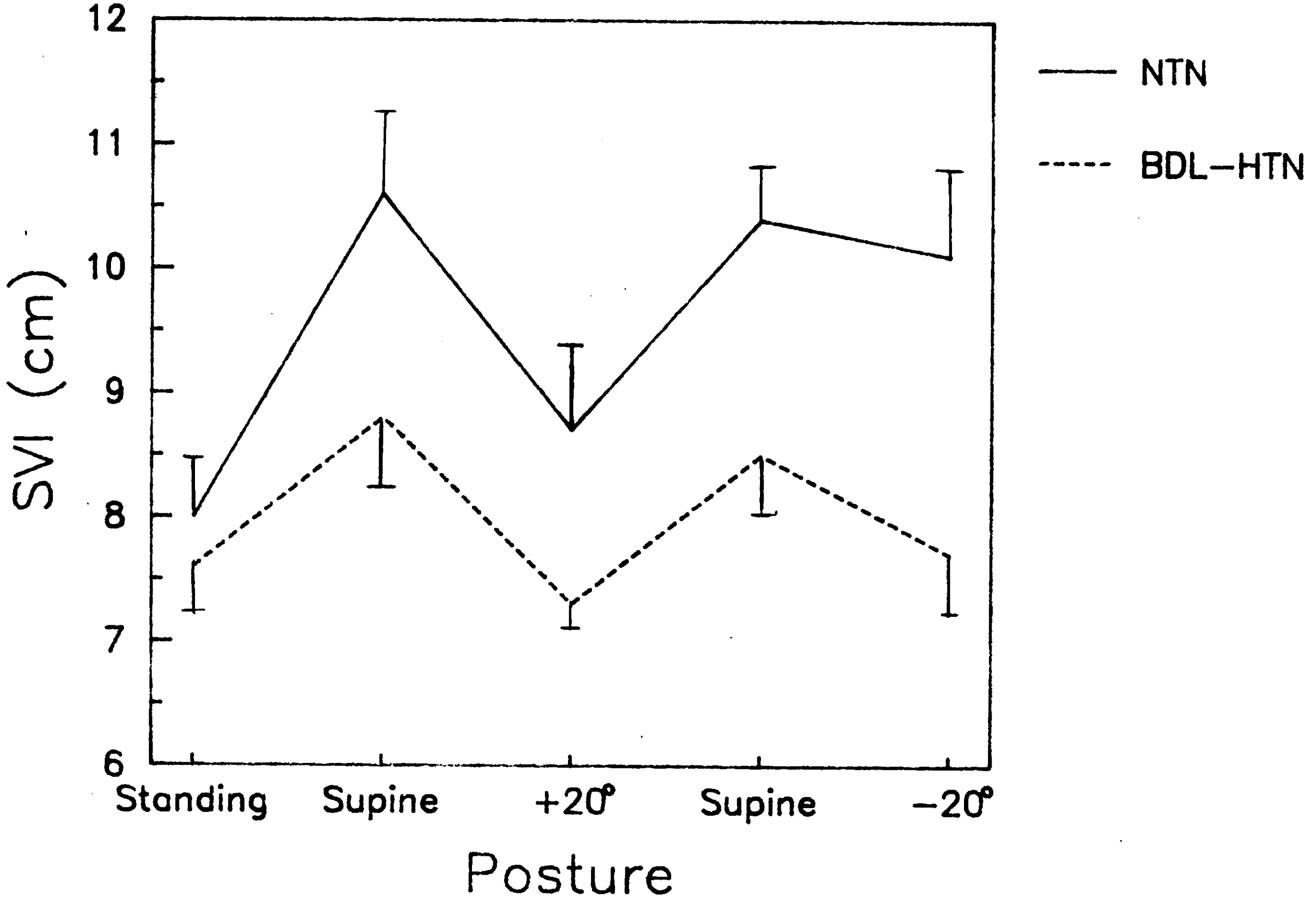

Figure 1. Effects of postural stress on stroke velocity integral (SVI) in normotensive (NTN) and borderline hypertensive (BDL−HTN) males.

Table 3. Effects of postural stress on hemodynamic measurement at rest.

Measurement	Posture SUP1		+20°		SUP2		-20°	
HR (b·min⁻¹)	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
NTN	61*	2.34	67	2.40	61	2.10	59	2.14
BDL-HTN	68*	2.71	70	2.59	64	2.32	63	2.37
SBP (mmHg)								
NTN	117*	2.12	119*	2.30	119*	1.68	121*	1.88
BDL-HTN	135*	2.11	136*	1.99	133*	2.15	136*	2.33
DBP (mmHg)								
NTN	66*	1.31	69*	1.52	65*	1.45	66*	1.72
BDL-HTN	82*	2.04	86*	1.96	79*	1.85	81*	1.44

Abbreviations: SUP1=supine 1; +20°=20° head-up; SUP2=supine 2; -20°=20° head-down; NTN=normotensive; BDL-HTN=boderline hypertensive.

*t>2.17, df=37, p<.05

Values shown are means and standard errors.

Discussion

The mean resting blood pressure, supine for the NTN group (117/66 mmHg) was considered normal by standards of the American Heart Association, while the values for the B-HTN group were slightly lower (139/84 mmHg) than the American Heart Association's definition for borderline hypertension (140/90mmHg).[3] The two groups were, however, significantly different (P<.05). Although the groups were not different for predicted body fat they were significantly different for body weight. It has been well documented that many individuals who become overweight also become hypertensive.[5,20]

The 15 minute period between each measurement was used in this study to allow the circulatory system time to stablize in each posture. Non-significant dependent t-test values confirmed that this interval was adequate for normalizing Doppler and hemodynamic responses between supine 1 and supine 2, despite the +20° postural stress which was interposed between the two supine measures. This finding increases confidence that the order of the postural tilt had no effect on the outcome of the study.

In all postural conditions, blood pressure responses were higher for the B-HTN group than for the NTN group. However, the postural shifts did not significantly affect blood pressure within either group (Table 3). Head-down tilting at levels between -10° to -20° for time periods similar to the one used in the present study has previously been demonstrated to increase blood pressure, stroke volume, and cardiac output via gravity-induced augmentation of venous return from the legs.[19] The treatments used in the present investigation (+20° and -20°) therefore, were anticipated to stimulate significant within group changes in blood pressure. This was not the case, however. More recent investigations have demonstrated that although increases in central venous pressure, ventricular preload and cardiac output result from tilting, the baroreceptor reflexes prevent a rise in arterial blood pressure.[14] Klatz et al.,[12] reported an increase in pulse rate and blood pressure in borderline hypertensive subjects when they were inverted -90°. This suggests that the degree of tilt has an effect on the degree of baroreceptor activity and the subsequent reflex decrease in heart rate and peripheral resistance. In fact, a decrease in heart rate has been consistently observed in both normal and tachycardic subjects with head-down tilting.[17] The increase in heart rate in the -90° position observed by Klatz et al.[12] may be due to a psychological mechanism.

Doppler measures of PkA, PkV, and SVI were higher for the NTN group than for the B-HTN group in all postures, though not always significantly so. Noble, et al.,[16] have shown that PkA is sensitive to inotropic state, and relatively insensitive to ventricular loading conditions. The findings of the present study support these observations. The reason for NTNs having a higher PkA in all postures may be due, in part, to a state of BP control achieved through a lower level of systemic arterial tone than in the B-HTN group, thus resulting in a higher PkA in NTNs, secondary to lower afterload.[4] Sympathetic nervous system activity and vascular sensitivity to adrenergic effects are both enhanced in practically all types of hypertension.[1,21] Among other effects, this increased sympathetic activity may cause increased vascular resistance, exaggeration of vasoconstrictor responses, and, chronically, an increased cellular production of vascular contractile protein. These mechanisms might be expected to lead to an increase in total peripheral resistance, thus causing both PkV and SVI to be lower by restricting blood flow.

Elkayam, et al.,[7] have shown that both SVI and PkV are affected by loading conditions and may provide an accurate assessment of changes in stroke volume. In the present study, SVI was the only Doppler measure significantly affected by changes in posture. The highest SVI values recorded for both groups were in the supine position. This is most likely due to increased venous return caused by the tilting effects of gravity. The greatest change occurred when NTN subjects were shifted from a standing to a supine postition for 15 minutes. This postural change resulted in a 34% increase in SVI for the NTN subjects, but only a 15% increase in SVI for the B-HTN subjects. Shifting from a standing to a supine position was apparently the most drastic ventricular loading increase of the experiment, if SVI change is accepted as indicative of stroke volume increase.

The increase in SVI which resulted from this standing to supine shift is in agreement with previous reports on the effects of postural changes on stroke volume (SV). Noble, et al.,[16] reported a 30% increase in SV in dogs when going from a sitting to a prone position. Abel and Waldhausen[2] also reported SV in dogs was maximal in the prone position decreasing 16.3% with sitting and 5.4% with standing on all four legs. The sitting position for a dog and the standing position for a human are similar in that they are both vertical. The physiological mechanism for the SV changes reported by Abel and Waldhausen[2] and the increase in SVI in the present study are likely reflections of increased venous return effects in the prone and supine positions, respectively.

It could be assumed that since the hydrostatic pressure is less in the supine position than in the upright position that it would be even less in a head-down tilt position thus increasing SV and SVI even further. This, however, was apparently not the case in the present study. Neither the NTN nor B-HTN groups showed statistically significant differences between these two postures. There was a tendancy for B-HTNs to decrease SVI slightly more (-9%) between supine and -20°. This may be due to the increased vascular resistance and increased sympathetic tone of these subjects.[1,21]

The literature is inconsistent on effects of head-down tilting relative to changes in SV. Abel and Waldhausen[2] reported a 21% increase in SV of anesthetized dogs when subjected to -20° head-down tilt, but an insignificant (+1.42%) change in unanesthetized dogs. Sibbald, et al.,[19] reported that after 3-5 minutes in the -20° head-down position preload of both ventricles was increased but SV was not significantly affected. Katkov et al.,[10] placed subjects in the -20° head-down position for 3 hours. They reported SV increased by an average of 20 $\text{ml}\cdot\text{bt}^{-1}$ over the first 15 minutes but, by the third hour, the level was back within 10 $\text{ml}\cdot\text{bt}^{-1}$ of resting supine values. Other investigators have reported varying effects of tilting on SV[9,13,15]. The activity of the baroreceptors, the degree of tilt and time in the position are variables which affect the results of these studies. In the present study, the failure of a -20° head-down tilt to significantly increase SVI may be due to the similarities of hydrostatic pressure and venous return associated with this position and the supine position. Thus the comparative difference in tilt may not have been a drastic enough change from the supine position to cause a greater venous return and higher SV.

Finally, the SVI response differences between NTNs and HTNs suggest that a postural stress test using CW Doppler ultrasound might be useful in early identification of individuals at risk for hypertension. Figure 2 illustrates the relationship between resting diastolic blood pressure and the percent change in SVI, observed when the subjects were tilted from standing to the supine position. The data in this figure suggest that the degree of altered vascular resistance to blood flow stimulated by extremes of tilting may be detected by such a test. Changes in

SV may be controlled by changes in total peripheral resistance (afterload) which is greater in hypertensives. In Figure 2, the horizontal line separates the subjects who had a change in SVI (sum of % change of standing to supine and supine to -20°) greater than 40% and those who had a change in SVI less than 40%. eighteen (95%) of the 20 B-HTNs experienced less than a 40% change in SVI. In the clinical context, these might be considered true positives for detection of borderline hypertensives using SVI response to tilting. There was also, however, a high number of false positives (65%). These findings suggest that SVI change with postural stress may have good predictive power for detection of borderline hypertension.

Further research is needed to examine the physiological differences in individuals with normal control of blood pressure and those with borderline hypertension as well as those with frank hypertension. A study examining familial pattern as a factor in hypertension as related to Doppler measured SVI might lead to improved methods of early identification of children predisposed to hypertension.

Place Figure 2 about here

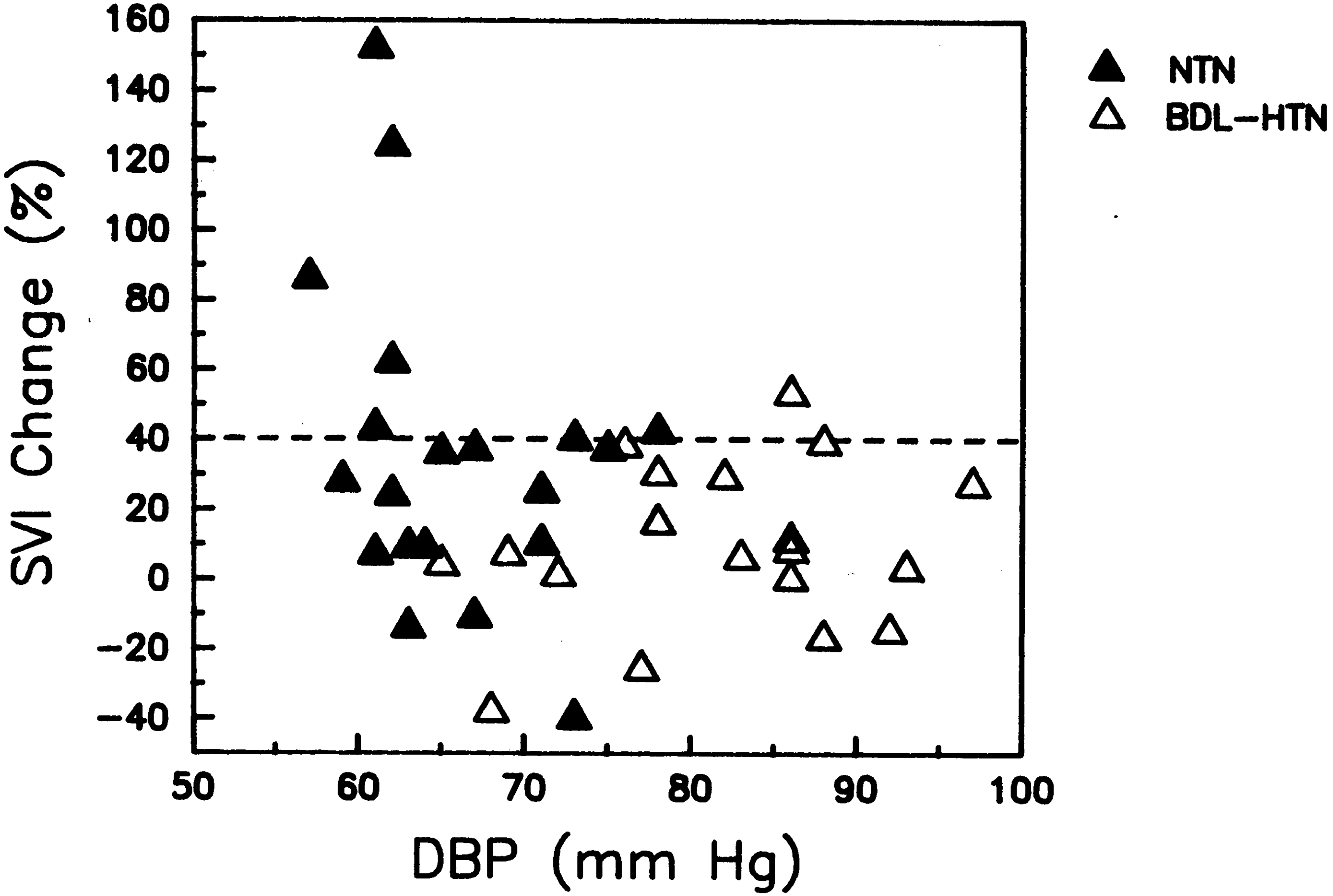

Figure 2. Relationship between resting diastolic blood pressure (DBP) and change in stroke velocity integral (SVI) (sum of per cent changes in standing−to−supine and supine−to−−20°).

In conclusion, the results of this study suggest a close relationship between SV and Doppler measured SVI. This supports the reports of Elkayam[7] that Doppler aortic blood flow measurements are useful in the assessment of changes in SV and SVR. These findings support other studies which have suggested that of the three Doppler measurements (PkA, PkV, and SVI) SVI is the most sensitive to loading conditions while PkA is the least sensitive. Finally, these results also add to the growing body of knowledge and understanding of the physiological differences between normal and hypertensive individuals.

REFERENCES

1. Abboud, F. (1982). The sympathetic system in hypertension. State-of-the-art review. Hypertension 4(Suppl. II): II-208-II-225.

2. Abel, F., Waldhausen, J. (1968). Influence of posture and passive tilting on venous return and cardiac output. American Journal of Physiology, 215 (5), 1058-1066.

3. American Heart Association. (1988). Heart Facts.

4. Bennet E., Barclay, S., Davis, A., Mannering, D., Nawzer, M. (1984). Ascending aortic blood velocity and acceleration using Doppler ultrasound in the assessment of left ventricular function. Cardiovascular Research, 18, 632-638.

5. Berchtold, P., Sims, E. (1981). Obesity and Hypertension: Conculusions and recommendations. International Journal of Obesity, 5(Suppl. 1):183-184.

6. Chandraratna, P., Silveria, B., Aronow, W. (1980). Assessment of left ventricular function by determination of maximum acceleration of blood flow in the aorta using continuous Doppler ultrasound. The Amercian Journal of Cardiology, 45, 398 (Abstract).

7. Elkayam, U., Gardin, J., Berkley, R., Hughes, C., Henry, W. (1983). The use of Doppler flow velocity measurement to assess the hemodynamic response to vasodilators in patients with heart failure. Circulation, 67(2), 377-383.

8. Gardin, J., Debastani, A., Matin, K., Allfie, A., Russell, D., Henry, W. (1984). Reproducibility of Doppler aortic flow measurements: studies on introbeserver, interobserver, and Day-to-Day variability in normal subjects. American Journal of Cardiology, 54, 1092-1098.

9. Jennings, T., Seaworth, J., Howell, L., Tripp, L., Goodyear, C. (1985). Effect of body inversion on hemodynamics determined by two-dimensional echocardiography. Critical Care Medicine, 13(9), 760-762.

10. Katkov, V., Chestukhin, V., Kakurin, L., Babin, A., Nikolaenko, E. (1987). Central and coronary circulation of the normal man during orthostatic and lower body negative pressure tests. Aviation, Space, and Environmental Medicine, 58(9), A55-60.

11. Khaja, F., Sabbah, H., Brymer, J., Goldstein, S., Stein, P. (1986). Noninvasive measurement of peak aortic blood acceleration with continuous wave doppler in patients experiencing chest pain during coronary angioplasty.

Clinical Research, 34, 313A (Abstract).

12. Klatz, R.M., Goldman, R.M., Pinchuk, B.G., Tarr, R.S. (1985). Effects of Gravity Inversion on Hypertensive Subjects. The Physician and Sports Medicine, 13(3) 85-89.

13. Lollgen, H., Gebhardt, U., Beier, J., Hordinsky, J., Borger, H., Sarrasch, V., Klein, K. (1984). Central hemodynamics during zero gravity simulated by head-down bedrest. Aviation, Space, and Environmental Medicine, 55(10), 887-892.

14. London, G.M., Levenson, J.A., Safar, M.E., Simon, A.C., Guerin, A.P., Payen, D. (1983). Hemodynamic effects of head-down tilt in normal subjects and sustained hypertensive patients. American Journal of Physiology 245: H194-H202.

15. Nixon, J., Murray, G., Leonard, P., Mitchell, J., Blomqvist, G. (1982). Effect of large variations in preload on left ventricular performance characteristics in normal subjects. Circulation, 65(4), 698-703.

16. Noble, I.M., Trenchard, D., Abraham, G., (1966). Left ventricular ejection in concious dogs: measurement and significance of the maximum acceleration of blood from the left ventricle. Circulation Research, 19, 139-147.

17. Razin, A. (1977). Upside-down position to terminate tachycardia of Wolff-Parkinson White Syndrome, letter. New England Journal of Medecine, 296, 1535.

18. Sabbah, H., Khaja, F., Brymer, J., McFarland, T., Albert, D., Snyder, J., Goldstein, S., Stein, P. (1986). Noninvasive evaluation of left ventricular performance based on peak aortic blood acceleration measured with a continuous wave Doppler velocity meter. Circulation, 74, 323-329.

19. Sibbald, W., Nigel, Paterson, A., Holliday, R., Baskerville, J. (1979). The trendelenburg position: hemodynamic effects in hypotensive and normotensive patients. Critical Care Medicine, 7(5), 218-224.

20. Sims, E. (1982). Mechanisms of hypertension in the overweight. Hypertension 4(Suppl. III):43-49.

21. Webb, R., Bohr, D. (1981). Recent adavances in the pathogenesis of hypertension: Consideration of structural, functional and metabolic vascular abnormalities resulting in elevated arterial resistance. American Heart Journal, 102:251-264.

Chapter IV

Summary and Research Recommendations

Summary

This study was conducted to assess the effects of body posture on continuous wave (CW) Doppler ultrasound measurements of peak acceleration (PkA), peak velocity (PkV), and systolic velocity integral (SVI) in normal and borderline hypertensive subjects. Specifically, the goals of the study were to assess the ability of the Quinton EXERDOP to detect changes in stroke volume (SV) and to examine possible detectable differences in Doppler blood flow parameters between normal and borderline hypertensive subjects.

Forty males, 19-61 years, participated in the study. Twenty of the subjects were free of any known coronary risk factors as specified by the American College of Sports Medicine (1986) and were on no medications. The other twenty subjects had been diagnosed by a physician as having borderline hypertension (≥140/90) and were on no medications.

Each individual was subjected to the same following procedures. The subject was asked to quietly stand erect for 3 minutes and then CW Doppler measurements of PkA, PkV, and SVI were taken from the suprasternal notch for 1 minute using a Quinton EXERDOP. The subject was then positioned on the padded tilt table in the supine position where he remained at rest for

15 minutes. At the end of 15 minutes, CW Doppler measurements were recorded from the suprasternal notch for 1 minute. Immediately following Doppler recordings, blood pressure (BP) and heart rate (HR) were measured using an electronic blood pressure system (Critikon Dinimap 845XT/XT-IEC).

The subject was then passively shifted into a +20° head-up position by a trained technician. The subject remained in this posture for 15 minutes. CW Doppler measurements were recorded for 1 minute following the 15th minute. Blood pressure and HR were recorded immediately following the Doppler recordings.

The subject was then returned to the supine position for another 15 minutes. Immediately following the 15th minute, CW Doppler measurements were recorded for 1 minute. Blood pressure and HR were recorded immediately following Doppler measurements.

Next, the subject was passively shifted to the -20° head-down position for 15 minutes. At the end of the 15th minute, CW Doppler measures were recorded for 1 minute. Blood pressure and HR were recorded immediately following Doppler measurements. Upon completion of the BP and HR recordings, the subject was returned to the supine position and the experiment was terminated.

A two-way Repeated Measures ANOVA was used to statistically analyze the data from the study. Interactions were determined across groups and postures for the dependent variables of PkA, PkV, SVI, HR, systolic blood pressure (SBP), and diastolic blood pressure (DBP). Significance was determined at the $p<.05$ level.

Each one-minute Doppler measurement period was divided into 3 20-second blocks, each of which were averaged by the EXERDOP's micro-computer. Pearson Product Moment correlations were used to estimate stability/reliablity of the Doppler measures. A dependent t-test was used to determine if supine Doppler measures were affected by the order or number of postures. Independent t-tests were used to determine differences between the two groups for age, BP, height, weight, and body fat.

The only significant interaction revealed by the two-way Repeated Measures ANOVA was with SVI. The normal group had consistently higher SVI than the hypertensive group across all postures. The biggest difference was seen when going from a standing to a supine posture. The mean SVI of the normal group increased by 34% while that of the hypertensive group increased only 15%.

The internal consistency correlations for the Doppler measures were high ranging from r=0.78 to r=0.98. The dependent t-test revealed that the order of postures had no effect on the supine values of Doppler measures thus supporting the theory that 15 minutes was long enough to allow the circulatory system to stabalize. Independent t-tests showed significant differences between groups for BP, height, and weight.

Conclusions

The results of the present study suggest that there exists a close relationship between cardiac stroke volume and Doppler measured SVI. These results support observations made by previous investigators that Doppler aortic blood flow measurements are useful in assessment of changes in stroke volume and systemic vascular resistance. The results of the present study also support previously published reports which have suggested that of the three Doppler measurements (PkA, PkV, SVI) SVI is the most sensitive to volumetric loading conditions.

The results of the present study also revealed that Doppler SVI response to postural stress (tilting) may have good predictive power for early detection of borderline hypertension. Finally, these results add to the growing body of knowledge and understanding of the physiological differences between normotensive and hypertensive individuals.

Recommendations for Future Research

The following are recommendations by the investigator for future research involving CW Doppler and/or hypertension.

1. A study examining how long it takes Doppler aortic blood flow measurements to return to baseline, if they do at all, in upright, supine, and inverted positions.
2. A study examining at exactly what angle of elevation and inversion do significant changes in stroke volume and SVI start to take place.

3. A study examining the effects of a cold pressor test on Doppler aortic blood flow measurements.
4. A study examining aortic blood flow differences in normotensives and frank hypertensives.
5. A study to examine different drug interventions on Doppler aortic blood flow measurements.
6. A study to examine the relationship between systemic vascular resistance (SVR) and SVI.
7. A study examining familial pattern as a factor in hypertension as related to Doppler measured SVI.

Recommendations for Clinical Practice

To date, Doppler ultrasound has been used only experimentally in the exercise laboratory. The results of the present study as well as an ever increasing number of other investigations suggest that in the future, Doppler ultrasound may be as common in the exercise laboratory as electrocardiography. The results of the present study suggest that CW Doppler ultrasound may be a valuable tool used by medical and clinical professionals in detecting and diagnosing many types of cardiovascular complications. Specifically, Doppler may be a useful tool in detecting individuals predisposed to hypertension and/or other circulatory abnormalities. With further refinement, a postural stress test involving Doppler measurement similar to the one used in this investigation might be used as a method of screening children and predicting the likelihood that they will have hypertension in the future. The early detection of hypertension can be most important in preventive medical approaches to controlling the effects of both coronary artery disease and stroke in our society.

REFERENCES

1. Abboud, F. (1982). The sympathetic system in hypertension. State-of-the-art review. Hypertension 4(Suppl. II): II-208-II-225.

2. Abel, F., Waldhausen, J. (1968). Influence of posture and passive tilting on venous return and cardiac output. American Journal of Physiology, 215 (5), 1058-1066.

3. American Heart Association. (1988). Heart Facts.

4. Bennet E., Barclay, S., Davis, A., Mannering, D., Nawzer, M. (1984). Ascending aortic blood velocity and acceleration using Doppler ultrasound in the assessment of left ventricular function. Cardiovascular Research, 18, 632-638.

5. Bennett, E., Else, W., Miller, G., Sutton, G., Miller, H., Noble, M. (1974) Maximum acceleration of blood from the left ventricle in patients with ischemic heart disease. Clinical Science and Molecular Medicine, 46, 49-59.

6. Berchtold, P., Sims, E. (1981). Obesity and Hypertension: Conculusions and recommendations. International Journal of Obesity, 5(Suppl. 1):183-184.

7. Bonde-Petersen, F., Christensen, N.J., Henriksen, O., Nielsen, B., Nielsen, C., Norsk, P., Rowell, L.B., Sadamoto, T., Sjogaard, G., Skagen, K., Suzuki, Y. (1980). Aspects of cardiovascular adaptation to gravitational stresses. The Physiologist, 23: Suppl., Dec., S7-S10.

8. Chandraratna, P., Silveria, B., Aronow, W. (1980). Assessment of left ventricular function by determination of maximum acceleration of blood flow in the aorta using continuous Doppler ultrasound. The Amercian Journal of Cardiology, 45, 398 (Abstract).

9. Creekmore, S., Graham, M., Jahn, G., Targett, R., Mcilroy, M. (1982). Comparison of methods of recording and analysis of Doppler blood velocity signals in normal subjects. Ultrasound in Medicine and Biology, 8(5), 525-535.

10. Elkayam, U., Gardin, J., Berkley, R., Hughes, C., Henry, W. (1983). The use of Doppler flow velocity measurement to assess the hemodynamic response to vasodilators in patients with heart failure. Circulation, 67(2), 377-383.

11. Gardin, J., Debastani, A., Matin, K., Allfie, A., Russell, D., Henry, W. (1984). Reproducibility of Doppler aortic flow measurements: studies on introbeserver, interobserver, and Day-to-Day variability in normal subjects. American Journal of Cardiology, 54, 1092-1098.

12. Goldman, R.M., Tarr, R.S., Pinchuk, B.G., Kappler, R.E. (1985). The effects of oscillating inversion on systemic blood pressure, pulse, intraocular pressure, and central retinal arterial pressure. The Physician and Sports Medicine, 13(3), 93-96.

13. Harrison, M., Smith, M. Friedman, B., Kwan, O., DeMaria, A. (1986). Doppler aortic flow velocities during exercise: relation to evidence of myocardial ischemia by thallium perfusion scitigraphy. Journal of the American College of Cardiology, 7:15A.

14. Hermiller, J., Walker, S., Binkley, P., Kidwell, G., Schaal, S., Wooley, C., Stang, J., Leier, C. (1984). The electrophysiologic effects of upright posture. American Heart Journal, 108, 1250-1254.

15. Hill, C. (1978). Ultrasonic attenuation and scattering by tissues, in deVlieger, M., Holmes, J., Klazner E., Kossof, G., et. al. (eds.): Handbook of Clinical Ultrasound New York, John Wiley & Sons, p. 15.

16. Huntsman, L., Stewart, D., Barnes, S., Franklin, S., Colocousis, J., Hessel, E. (1983). Noninvasive determination of cardiac output in man. Circulation, 67, 593-602.

17. Jackson, A., Pollock, M. (1978). Generalized equations for predicting body density of men. British Heart Journal, 54, 378-383.

18. Jennings, T., Seaworth, J., Howell, L., Tripp, L., Goodyear, C. (1985). Effect of body inversion on hemodynamics determined by two-dimensional echocardiography. Critical Care Medicine, 13(9), 760-762.

19. Jewitt, d., gabe, I., Mills, C., Maurer, B., Thomas, M., Shillingford, J. (1974). Aortic velocity and acceleration measurements in the assessment of coronary heart disease. European Journal of Cardiology, 113, 299-305.

20. Katkov, V., Chestukhin, V., Lapteva, R., Yakovleva, V., Mikhailov, V., Zybin, O., Utkin, V. (1979). Central and cerebral hemodynamics and metabolism of healthy man during head-down tilt. Aviation, Space, and Environmental Medicine, 502(2), 147-153.

21. Katkov, V., Chestukhin, V. (1980). Blood pressure and oxygenation in different cardiovascular compartments of a normal man during postural exposures. Aviation, Space, and Environmental Medicine, 51(11), 1234-1242.

22. Katkov, V., Chestukhin, V., Kakurin, L., Babin, A., Nikolaenko, E. (1987). Central and coronary circulation of the normal man during orthostatic and lower body negative pressure tests. Aviation, Space, and Environmental Medicine, 58(9), A55-60.

23. Kelly, T., Rothbart, R., Patrone, V. Moore, J., Watson, D., Gibson, R. (1986). Suprasternal exercise Doppler (EXERDOP): Feasibility and results in normals and patients with suspected coronary disease. Journal of the American College of Cardiology, 7(2), 15A (Abstract).

24. Khaja, F., Sabbah, H., Brymer, J., Goldstein, S., Stein, P. (1986). Noninvasive measurement of peak aortic blood acceleration with continuous wave doppler in patients experiencing chest pain during coronary angioplasty. Clinical Research, 34, 313A (Abstract).

25. Klatz, R.M., Goldman, R.M., Pinchuk, B.G., Tarr, R.S. (1985). Effects of Gravity Inversion on Hypertensive Subjects. The Physician and Sports Medicine, 13(3) 85-89.

26. Knitelius, H., Stegemann, J., (1987). Heart volume during short-term head-down tilt (-6) in comparison with horizontal body position. Aviation, Space, and Environmental Medicine, 58(9) A61-63.

27. Lamb, D. (1985) Physiology of Exercise Responses and Adaptations. Macmillan Publishing Co. New York. P. 373.

28. Lambert, C., Nichols, W., Pepine, C. (1982). Indicies of ventricular contractile state: Comparative sensitivity and specificity. American Heart Journal, 106, 136-144.

29 Loepky, J., Greene, E., Hoekenga, D., Caprihan, A., Luft, U. (1981). Beat-by-Beat stroke volume assessment by pulsed Doppler in upright and supine exercise. Journal of Applied Physiology, 50, 1173-1182.

30. Lollgen, H., Gebhardt, U., Beier, J., Hordinsky, J., Borger, H., Sarrasch, V., Klein, K. (1984). Central hemodynamics during zero gravity simulated by head-down bedrest. Aviation, Space, and Environmental Medicine, 55(10), 887-892.

31. London, G.M., Levenson, J.A., Safar, M.E., Simon, A.C., Guerin, A.P., Payen, D. (1983). Hemodynamic effects of head-down tilt in normal subjects and sustained hypertensive patients. American Journal of Physiology 245: H194-H202.

32. Lynch, J.J., Long, J.M., Thomas, S.A., Malinow, K.L., Katcher, A.H. (1981). The effects of talking on the blood

pressure of hypertensive and normotensive individuals. Psychosomatic Medicine, 43(1), 25-33.

33. Mehta, N., Bennett, D., Dawkins, K., Ward, D., Mannering, D. (1986). Doppler monitored hemodynamic response and early ischemia in exercise stress testing predicts triple vessel disease. Journal of The American College of Cardiology, 7(2), 16A (Abstract).

34. Murco, P., Altobelli, S., Dorethy J., Logsdon, J., McGranahan, G. (1974). Normal ventricular ejection dynamics in man during rest and exercise. American Heart Association Monograph, 46, 92-101.

35. Nixon, J., Murray, G., Leonard, P., Mitchell, J., Blomqvist, G. (1982). Effect of large variations in preload on left ventricular performance characteristics in normal subjects. Circulation, 65(4), 698-703.

36. Noble, I.M., Trenchard, D., Abraham, G., (1966). Left ventricular ejection in concious dogs: measurement and significance of the maximum acceleration of blood from the left ventricle. Circulation Research, 19, 139-147.

37. Pearlman, A., Stevenson, J., Baker, D. (1980). Doppler echocardiography: applications, limitations and future directions. The American Journal of Cardiology, 46, 1256-1262.

38. Razin, A. (1977). Upside-down position to terminate tachycardia of Wolff-Parkinson White Syndrome, letter. New England Journal of Medecine, 296, 1535.

39. Rushmer, R.F. (1964). Initial ventricular impulse - A potential key to cardiac evaluation. Circulation, 29, 280-283.

40. Sabbah, H., Khaja, F., Brymer, J., McFarland, T., Albert, D., Snyder, J., Goldstein, S., Stein, P. (1986). Noninvasive evaluation of left ventricular performance based on peak aortic blood acceleration measured with a continuous wave Doppler velocity meter. Circulation, 74, 323-329.

41. Sabbah, H., Przybylski, J., Albert, D., Stein, P. (1987). Peak aortic blood acceleration reflects the extent of left ventricular ischemia mass at risk. American Heart Journal, 113, 885-890.

42. Shaw, G., Johnson, C., Voyles, W., Greene, E. (1985). Noninvasive Doppler determination of cardiac output during submaximal and peak exercise. American Journal of Physiology, May, 722-731.

43. Sibbald, W., Nigel, Paterson, A., Holliday, R., Baskerville, J. (1979). The trendelenburg position: hemodynamic effects in hypotensive and normotensive patients. Critical Care Medicine, 7(5), 218-224.

44. Sims, E. (1982). Mechanisms of hypertension in the overweight. Hypertension 4(Suppl. III):43-49.

45. Spencer, M., Greiss, F. (1962). Dynamics of ventricular ejection. Circulation Research, 10, 274-279.

46. Stein, P., Sabbah, H. (1976a). Rate of change of ventricular power: An indicator of ventricular performance during ejection. American Heart Journal, 91, 219-227.

47. Stein, P., Sabbah, H. (1976b). Ventricular performance measured during ejection: studies in patients of the rate of change of ventricular power. American Heart Journal, 91(5), 599-606.

48. Stein, P., Sabbah, K., Albert, D., Snyder, J. (1985). Blood velocity and acceleration: Comparison of CW Doppler and Electromagnetic Flowmetry. Federation Proceedings, 44, 1565.

49. Taylor, J., Weil, M. (1967). Failure of the Trendelenburg position to improve circulation during clinical shock. Surgical Gynecology and Obstetrics, 124:1005-1010.

50. Teague, S., Corn, C., Sharma, M., Prasad, R., Burow, R., Voyles, W., Thadani, U. (1987). A comparison of Doppler and radionuclide ejection dynamics during ischemic exercise. American Journal of Cardiac Imaging, Vol. 1 No. 2, 145-151.

51. Tomaselli, C., Kenney, R., Frey, M., Hoffler, W. (1987). Cardiovascular dynamics during the initial period of head-down tilt. Aviation, Space and Environmental Medicine 58, 3-8.

52. Vijayarghavan, G., Singham, K., Tei, C., Wong, A., Wong, M., Shah, P. (1984). Aortic flow velocity in older subjects using continuous wave Doppler echocardiography. American Heart Journal, 107(6), 1275-1276 (Brief Communications).

53. Webb, R., Bohr, D. (1981). Recent adavances in the pathogenesis of hypertension: Consideration of structural, functional and metabolic vascular abnormalities resulting in elevated arterial resistance. American Heart Journal, 102:251-264.

Appendix A

Methodology

Selection of Subjects

Prior to selection of the subjects, clearance to perform the experimental procedures was secured from the University's Human Subjects Committee (Appendix B). The 39 male subjects selected to participate in this study were volunteers. Twenty of the subjects were free of any known risk factors as specified by the American College of Sports Medicine (1986) and were on no medications. The other nineteen subjects had been diagnosed by a physician as having borderline hypertension and were on no medications. The twenty normal subjects were screened for the CHD risk factors of hypertension and obesity. The subjects were males aged 19-47 years, and moderately physically active (exercise at least three times a week for 20 minutes or more but not more than six times a week for 2 hours or more).

Sampling Procedures

The subjects were a sample of the Virginia Tech male population of students, faculty, and staff. All of the subjects were volunteers.

GENERAL METHOD

Instructional Procedures

During a preliminary orientation period, each subject was briefed as to the nature of the experiment, its purpose, possible risk to the participants, and its research implications. Written informed consent was obtained from each subject (Appendix C). Each subject was required to complete a medical history questionnaire (Appendix D). Next, the subject was familiarized with the tilt table and the EXERDOP. The subject was then placed on the tilt table in a supine position and asked to relax for 2 minutes in this posture. The subject was shifted into the 20° head-up position where he remained for 2 minutes. Next the subject was returned to the supine position for 30 seconds and then shifted into the -20° head down position where he remained for 2 minutes. In each posture the investigator instructed the subject to relax completely. The investigator also demonstrated the placement of the EXERDOP probe in each of the positions in order to remove any apprehension about the procedure.

Reliability Estimates

To estimate the internal consistency of the measurement technique utilized in this study, Each one minute measurement period was divided into three 20-second blocks. The average value for each 20-second block was used as the criterion measure and Pearson Product-Moment correlations were computed for each posture and Doppler variable to estimate the internal consistency.

Validity Estimate

In order to validate the utilization of the EXERDOP as a means of assessing left ventricular function, literature relating to continuous-wave (CW) Doppler research was reviewed. CW Doppler techniques have been compared with various cardiac functional measurements obtained by radionuclide procedures (Teague, Corn, Sharma, Prasad, Burow, Voyles, & Thadani, 1987), electromagnetic flowmetry (Stein, Sabbah, Albert, & Snyder 1985), and thermodilution (Huntsman, Stewart, Barnes, Franklin, Colocousis, & Hessel, 1983). In each case, CW Doppler was reported to be a valid instrument for non-invasively assessing left ventricular function.

Experimental Procedures

Prior to this investigation, a pilot study was conducted by the investigator to gain competence with the testing procedure and also to confirm the ability of the EXERDOP to detect aortic blood flow impulses in all three posture positions.

On the day of testing, each subject was briefed by the investigator to explain the requirements of the experiment and to insure that the subject had not participated in any strenuous activity that day. The investigation was conducted in a quiet, controlled environment.

The following experimental procedures were followed for each subject. The subject was asked to quietly stand erect for 3 minutes and then CW Doppler measurements of peak acceleration (PkA), peak velocity (PkV), and systolic velocity integral (SVI) were taken from the suprasternal notch for 1 minute using a Quinton EXERDOP. The angle at which the probe was held was determined by the auditory signal that was proportional to the reception of sound waves being reflected. This was monitored by the investigator. The subject was then positioned on the padded tilt table in the supine position, and remained at rest for 15 minutes. At the end of 15 minutes, CW Doppler measurements were recorded from the suprasternal notch for 1 minute. Immediately following Doppler recordings, blood pressure (BP) and heart rate (HR) were measured using an electronic blood pressure system (Critikon Dinamap 845XT/XT-IEC).

The subject was then passively shifted into a 20° head-up position by a trained technician. The shift from one posture to another took no longer than 5 seconds. The subject remained in this position for 15 minutes. CW Doppler measurements were recorded from the suprasternal notch immediately following the

15th minute. Blood pressure and HR were recorded immediately following the recording of Doppler measurements.

Next, the subject was returned to the supine position for 15 minutes. At the end of the 15th minute, CW Doppler measurements were recorded from the suprasternal notch. Blood pressure and HR were recorded immediately following the Doppler measurements.

Next, the subject was passively shifted into the -20° head-down position where he remained for 15 minutes. CW Doppler measurements were recorded immediately following the 15th minute. Blood pressure and HR were measured immediately following the completion of the Doppler recordings. Upon completion of the BP and HR recordings, the subject was returned to the supine position and the experiment was terminated.

Research Design

A repeated-measures design was used. Both groups of subjects (normotensivess and borderline hypertensives) received the same treatments in the same order. The order of treatments was supine, +20° head-up, supine, -20° head-down.

External Validity

The characteristics of the subjects; males, 19-47 years of age, allow the experimental findings of this study to be generalized to a population of similar characteristics.

Internal Validity

Extraneous variance in this investigation was minimized by a) training the technician assisting in data collection, and b) orienting the subjects to the procedures before the actual test.

Statistical Procedures and Data Analysis

Statistical analysis included a two-way repeated measures ANOVA employed to determine interactions across groups and postures for each dependent measure of PkA, PkV, SVI, HR, systolic blood pressure (SBP), and diastolic blood pressure (DBP). Internal consistency coefficients for the Doppler measurements were estimated by dividing each one minute measurement period into three 20-second blocks and correlating the average of each 20-second block with the other two blocks using Pearson Product-Moment correlations. A dependent t-test procedure also was used to determine if supine Doppler responses were affected by the order or number of postural trials. Statistical significance was determined at the $p < .05$ level.

APPENDIX B
HUMAN SUBJECTS COMMITTEE APPROVAL

CERTIFICATION OF EXEMPTION OF PROJECTS INVOLVING HUMAN SUBJECTS

Principal Investigator(s) Ray William (Bill) Morris

Department(s) HPER (College of Education)

Project Title Effects of Posture on CW Doppler Measurements in Normotensives vs. Hypertensives

Source of Support: Departmental Research X Sponsored Research __ Proposal No. ______

1. The criteria for "exemption" from review by the IRB for a project involving the use of human subjects and with no risk to the subject is listed below. Please initial all applicable conditions and provide the substantiating statement of protocol.

☒ a. The research will be conducted in established or commonly established educational settings, involving normal education practices. For example:
   - a) Research on regular and special education instructional strategies;
   - b) Research on effectiveness of instructional techniques, curricula or classroom management techniques.

☐ b. The research involves use of education tests (☐ cognitive, ☐ diagnostic, ☐ aptitude, ☐ achievement), and the subject cannot be identified directly or through identifiers with the information.

☒ c. The research involves survey or interview procedures, in which:
   - ☐ a) Subjects cannot be identified directly or through identifiers with the information;
   - ☒ b) Subject's responses, if known, will not place the subject at risk of criminal or civil liability or be damaging to the subject's financial standing or employability;
   - ☒ c) The research does not deal with sensitive aspects of subject's own behavior (illegal conduct, drug use, sexual behavior or alcohol use);
   - ☐ d) The research involves survey or interview procedures with elected or appointed public officials, or candidates for public office.

__ d. The research involves the observation of public behavior, in which:
   - ☐ a) The subjects cannot be identified directly or through identifiers;
   - ☐ b) The observations recorded about an individual could not put the subject at risk of criminal or civil liability or be damaging to the subject's financial standing or employability;
   - ☐ c) The research does not deal with sensitive aspects of the subject's behavior (illegal conduct, drug use, sexual behavior or use of alcohol).

__ e. The research involves collection or study of existing data, documents, reports, pathological specimens or diagnostic specimens, or which:
   - ☐ a) The sources are publicly available; or
   - ☐ b) The information is recorded such that the subject cannot be identified directly or indirectly through identifiers.

I further certify that the project will not be changed to increase the risk or exceed the exempt condition(s) without filing an additional certification or application for approva by the Human Subjects Review Board.

te: If children are in any way at risk while this project is underway, the chairman of the IRB should be notified immediately in order to take corrective action.

nature: Principal Investigator(s) Date ______ Signature: Principal Investigator(s) Date

tional Approval) Signature: Board Chairman/Authorized Reviewer ______ Date

APPENDIX C
INFORMED CONSENT

HUMAN PERFORMANCE LABORATORY

Division of Health, Physical Education and Recreation
Virginia Polythechnic Institute and State University

INFORMED CONSENT

I, _______________, do hereby voluntarily agree and consent to participate in a testing program conducted by the personnel of the Human Performance Laboratory of the Division of Health, Physical Education and Recreation of Virginia Polytechnic Institute and State University.

Title of Study: The Effects of Posture on Continuous-Wave Doppler Measurements in Normotensives and Borderline Hypertensives.

The purposes of this experiment include:

1) To examine differences in CW Doppler measurements (SVI, PkA, PkV) and heart rate and blood pressure between three different postures (supine, +20° head-up, and -20° head-down).
2) To examine differences in CW Doppler measurements and heart rate and blood pressure between normotensive individuals and borderline hypertensives (BP ≥ 140/90).

I voluntarily agree to participate in this testing program. It is my understanding that my participation will include:

1) Answering questions concerning my medical history.
2) Being placed in the following postures for up to 15 min. each: supine, +20° head-up tilt, -20° head-down tilt.
3) Having CW Doppler measurements taken from the suprasternal notch while in these postures.

I understand that participation in this experiment may produce certain discomforts and risks. These discomforts and risks include:

1) Possible feeling of slight discomfort (mild head ache) during -20° head-down tilt.

Certain personal benefits may be expected from participation in this experiment. These include:

1) Possibly gaining knowledge of the control of blood pressure and blood flow.
2) Having my blood pressure checked.
3) Having my body composition analysis done.

Appropriate alternative procedures that might be advantageous to you include:

None

I understand that any data of a personal nature will be held confidential and will be used for research purposes only. I also understand that these data may only be used when not identifiable with me.

I understand that I may abstain from participation in any part of the experiment or withdraw from the experiment should I feel the activities might be injurious to my health. The experimenter may also terminate my participation should he feel the activities might be injurious to my health.

I understand that it is my personal responsibility to advise the researchers of any preexisting medical problem that may affect my participation or of any medical problems that might arise in the course of this experiment and that no medical treatment or compensation is available if injury is suffered as a result of this research. A telephone is available which would be used to call the local hospital for emergency service.

I have read the above statements and have had the opportunity to ask questions. I understand that the researchers will, at any time, answer my inquiries concerning the procedures used in this experiment.

Scientific inquiry is indispensable to the advancement of knowledge. Your participation in this experiment provides the investigator the opportunity to conduct meaningful scientific observations designed to make significant educational contribution.

If you would like to receive the results of this investigation, please indicate this choice by marking in the appropriate space provided below. A copy will then be distributed to you as soon as the results are made available by the investigator. Thank you for making this important contribution.

_____I request a copy of the results of this study.

Date__________, Time__________a.m. p.m.

Participant Signature______________________________

Witness________________________________

HPL Personnel

Project Director__________________Telephone______________

HPER Human Subjects Chairman Dr. Charles Baffi Telephone 961-5104

Dr. Charles Waring, Chairman, Institutional Review Board for

Research Involving Human Subjects. Phone 961-5283.

APPENDIX D
MEDICAL HISTORY QUESTIONNAIRE

MEDICAL HISTORY QUESTIONNAIRE

Name:________________ Age:_____ Ht:_____
Date:_____________ Sex: M F Wt:_____

1) Have you ever been told by a physician that you have high blood pressure? yes no

2) Please list any medications you are currently taking.

3) Do you have a history of fainting or dizzy spells? yes no

4) Have you ever suffered from migraine head aches? yes no
If yes, explain:

5) Do you, or have you ever sufferred from neck or back injuries? yes no If yes, explain:

6) List any other orthopedic or musculoskeletal disorders that you may have:

7) Indicate your current level of physical activity:

___Sedentary- Never exercise at all.

___Moderately Active- Exercise 3-7 times a week for 20-90 minutes continuously per session.

___High level of physical activity- Exercise 6 times or more a week for 2 hours or more continuously per session.

List the physical activities in which you regularly participate:

I certify that the above information is correct
signature____________________date___________

APPENDIX E
RAW DATA

```
-
------------------------------------NCSS------------------------------------
Date:               01-01-1980
Time:               01:03:00
Data Base Name:     EXAMPLE
Description:
Backup of    Repeated measures two-way anova for thesis

Column:          1         2         3         4         5         6         7

     1         1.00      1.00     28.00    170.20     68.50     13.30     19.00
     2         2.00      1.00     34.00    172.00     76.00     10.40     12.00
     3         3.00      1.00     24.00    179.50     81.00     18.00     11.00
     4         4.00      1.00     25.00    182.00     73.00     10.20     14.00
     5         5.00      1.00     40.00    192.00     95.00     14.70     13.00
     6         6.00      1.00     23.00    164.00     85.60     15.50     15.00
     7         7.00      1.00     27.00    171.00     77.50      6.80     16.00
     8         8.00      1.00     26.00    164.00     68.00     10.60     14.00
     9         9.00      1.00     43.00    180.00     75.00     13.20      9.00
    10        10.00      1.00     21.00    170.00     81.50     16.00     13.00
    11        11.00      1.00     26.00    178.00     74.00     10.60     13.00
    12        12.00      1.00     23.00    186.50     94.00      8.00     17.00
    13        13.00      1.00     22.00    175.00     90.50      8.00     17.00
    14        14.00      1.00     35.00    176.00     69.00      7.90     15.00
    15        15.00      1.00     23.00    165.00     65.00      4.60     19.00
    16        16.00      1.00     25.00    176.00     99.50     15.00     14.00
    17        17.00      1.00     23.00    180.00     80.00      9.30     14.00
    18        18.00      1.00     24.00    173.00     65.30      8.40     23.00
    19        19.00      1.00     22.00    182.00     84.50      9.90     21.00
    20        20.00      1.00     21.00    174.00     78.20     15.20     15.00
    21        21.00      2.00     26.00    186.00     92.50     12.90      8.00
    22        22.00      2.00     21.00    172.00     70.00     10.70     13.00
    23        23.00      2.00     21.00    180.00     72.70     10.70     19.00
    24        24.00      2.00     23.00    179.00     83.50     12.10     10.00
    25        25.00      2.00     26.00    171.00     76.50      9.70     11.00
    26        26.00      2.00     25.00    188.00     80.50     12.70     16.00
    27        27.00      2.00     21.00    187.00    116.00     16.00     14.00
    28        28.00      2.00     23.00    185.00    100.70      9.30     14.00
    29        29.00      2.00     23.00    172.50     80.00     10.20     16.00
    30        30.00      2.00     23.00    189.00     92.50      6.50     14.00
    31        31.00      2.00     28.00    180.00     78.00     19.20     16.00
    32        32.00      2.00     28.00    185.00     80.00     16.70     19.00
    33
    34        34.00      2.00     19.00    189.00    116.50     20.10     15.00
    35        35.00      2.00     22.00    183.00    100.00     13.10      9.00
    36        36.00      2.00     30.00    179.00    100.00     17.10     13.00
    37        37.00      2.00     28.00    178.00     96.00      9.40     16.00
    38        38.00      2.00     22.00    179.00     83.00     10.70     16.00
    39        39.00      2.00     47.00    177.00    104.00     28.40      8.00
    40        40.00      2.00     22.00    198.00    107.50     10.20     14.00

          Col(  1)sub
          Col(  2)grp
          Col(  3)age
          Col(  4)ht
          Col(  5)wt
          Col(  6)bf
          Col(  7)stpka
```

```
----------------------------------NCSS-----------------------------------
Date:                 01-01-1980
Time:                 00:59:49
Data Base Name:       EXAMPLE
Description:
Backup of    Repeated measures two-way anova for thesis

Column:            8         9        10         11        12        13        14

        1        0.84     13.00     40.00      1.02     16.00     68.00    116.00
        2        0.53      6.80     17.00      0.71      8.60     48.00    117.00
        3        0.50      5.60     14.00      0.64      8.00     71.00    106.00
        4        0.62      6.80     17.00      0.73      8.20     51.00    122.00
        5        0.64      7.20     11.00      0.56      8.60     49.00    107.00
        6        0.55      7.80     20.00      0.72     11.80     78.00    129.00
        7        0.64      7.40     17.00      0.76     13.80     54.00    113.00
        8        0.61      8.40     12.00      0.57     11.00     49.00     98.00
        9        0.38      7.00     10.00      0.52     11.40     47.00    112.00
       10        0.55      5.80     13.00      0.60      8.00     68.00    115.00
       11        0.46      4.60     12.00      0.59     11.60     60.00    102.00
       12        0.76      9.20     21.00      0.97     13.80     64.00    130.00
       13        0.89     14.20     22.00      1.04     15.00     50.00    124.00
       14        0.71      7.80     16.00      0.73      8.40     55.00    131.00
       15        0.79      9.20     16.00      0.70      9.00     61.00    125.00
       16        0.56      6.80     26.00      0.67     11.00     70.00    112.00
       17        0.63      7.20     15.00      0.70      8.20     56.00    111.00
       18        0.78      7.80     19.00      0.88     10.80     70.00    121.00
       19        0.88     11.40     27.00      0.86     12.60     62.00    122.00
       20        0.54      5.40     14.00      0.56      7.40     82.00    127.00
       21        0.41      5.00     11.00      0.52      6.60     79.00    125.00
       22        0.58      7.00     10.00      0.44      5.40     64.00    138.00
       23        0.83     11.00     25.00      1.07     13.40     50.00    141.00
       24        0.48      6.40     13.00      0.56      7.20     63.00    120.00
       25        0.61     10.60     13.00      0.69     13.00     49.00    131.00
       26        0.75      9.00     15.00      0.73      9.40     64.00    142.00
       27        0.55      7.00     19.00      0.59      6.40     75.00    158.00
       28        0.65      8.00     14.00      0.64      9.80     55.00    140.00
       29        0.57      6.00     13.00      0.48      5.60     91.00    120.00
       30        0.71      8.40     16.00      0.84     10.80     69.00    142.00
       31        0.72      9.80     16.00      0.77     11.00     66.00    132.00
       32        0.79     11.80     19.00      0.75      9.80     75.00    142.00
       33
       34        0.67      7.80     18.00      0.73      8.40     71.00    137.00
       35        0.42      4.40     13.00      0.55      7.40     88.00    129.00
       36        0.58      6.60     16.00      0.69      8.20     81.00    135.00
       37        0.73      9.80     16.00      0.74     10.80     61.00    141.00
       38        0.73      8.00     14.00      0.62      7.00     54.00    142.00
       39        0.33      3.80      9.00      0.37      6.60     66.00    129.00
       40        0.59      9.20     13.00      0.56     12.20     63.00    128.00

          Col(  8)stpkv
          Col(  9)stsvi
          Col( 10)s1pka
          Col( 11)s1pkv
          Col( 12)s1svi
          Col( 13)s1hr
          Col( 14)s1sbp
```

```
------------------------------------NCSS------------------------------------
Date:             01-01-1980
Time:             01:00:34
Data Base Name:   EXAMPLE
Description:
Backup of   Repeated measures two-way anova for thesis


Column:          15        16        17        18        19        20        21

     1        67.00     16.00      0.74     12.00     70.00    119.00     67.00
     2        71.00     11.00      0.53      5.20     61.00    125.00     78.00
     3        62.00     12.00      0.56      7.80     75.00    114.00     61.00
     4        61.00     12.00      0.53      6.20     60.00    114.00     56.00
     5        67.00     11.00      0.60      7.00     60.00    137.00     76.00
     6        78.00     24.00      0.71      9.60     83.00    129.00     82.00
     7        57.00     12.00      0.57      9.60     63.00    107.00     60.00
     8        62.00     17.00      0.75     13.00     52.00    102.00     62.00
     9        61.00     14.00      0.64     12.00     61.00    105.00     69.00
    10        61.00     13.00      0.55      7.00     74.00    116.00     72.00
    11        62.00     11.00      0.48      6.60     68.00    103.00     72.00
    12        65.00     19.00      0.91     11.60     66.00    137.00     72.00
    13        64.00     16.00      0.79     11.60     48.00    122.00     65.00
    14        71.00     16.00      0.73      8.20     66.00    123.00     74.00
    15        73.00     16.00      0.70      8.40     62.00    113.00     66.00
    16        63.00     14.00      0.57     10.00     72.00    123.00     64.00
    17        59.00     12.00      0.58      6.20     67.00    117.00     70.00
    18        73.00     19.00      0.84      8.80     83.00    128.00     75.00
    19        63.00     16.00      0.65      8.40     55.00    129.00     69.00
    20        75.00     13.00      0.52      5.60     91.00    123.00     78.00
    21        76.00      9.00      0.44      5.80     80.00    129.00     81.00
    22        88.00      9.00      0.40      5.00     68.00    136.00     80.00
    23        65.00     21.00      0.93     11.20     57.00    137.00     66.00
    24        78.00     11.00      0.43      5.00     56.00    130.00     88.00
    25        69.00     12.00      0.62     11.20     52.00    130.00     78.00
    26        72.00     13.00      0.68      8.00     61.00    146.00     80.00
    27        93.00     17.00      0.64      6.60     83.00    154.00    104.00
    28        78.00     18.00      0.84     10.80     66.00    126.00     85.00
    29        68.00     12.00      0.45      5.60     89.00    122.00     68.00
    30        88.00     11.00      0.57      7.20     69.00    148.00     86.00
    31        86.00     11.00      0.55      7.40     60.00    136.00     88.00
    32        92.00     18.00      0.71      9.00     76.00    142.00     85.00
    33
    34        77.00     16.00      0.76      8.60     78.00    148.00     87.00
    35        86.00     12.00      0.54      6.40     83.00    140.00     80.00
    36        85.00     14.00      0.62      6.80     88.00    141.00     90.00
    37        83.00     13.00      0.65      9.20     61.00    138.00     84.00
    38        86.00     11.00      0.47      5.20     60.00    137.00     79.00
    39        97.00     10.00      0.38      4.80     68.00    126.00     95.00
    40        82.00      9.00      0.42      9.00     70.00    129.00     79.00


          Col( 15)s1dbp
          Col( 16)upka
          Col( 17)upkv
          Col( 18)usvi
          Col( 19)uhr
          Col( 20)usbp
          Col( 21)udbp
```

```
------------------------------------NCSS-------------------------------------
Date:                 01-01-1980
Time:                 01:01:19
Data Base Name:       EXAMPLE
Description:
Backup of   Repeated measures two-way anova for thesis

Column:          22         23         24         25         26         27         28

      1       20.00       1.01      14.80      72.00     115.00      57.00      19.00
      2       18.00       0.77       9.00      67.00     132.00      79.00      15.00
      3       12.00       0.53       9.60      71.00     118.00      68.00      13.00
      4       14.00       0.63       7.20      53.00     114.00      54.00      14.00
      5       12.00       0.60       7.40      50.00     122.00      63.00      10.00
      6       22.00       0.83      14.00      72.00     126.00      76.00      22.00
      7       19.00       0.78      13.60      53.00     113.00      57.00      18.00
      8       12.00       0.56      10.40      53.00     107.00      60.00      13.00
      9       16.00       0.71      14.80      48.00     115.00      65.00      15.00
     10       12.00       0.51       7.00      65.00     120.00      64.00      11.00
     11       11.00       0.53      10.00      60.00     103.00      62.00      10.00
     12       20.00       0.85      11.40      63.00     131.00      61.00      15.00
     13       16.00       0.81      12.40      47.00     129.00      60.00      18.00
     14       14.00       0.66       7.60      55.00     120.00      67.00      15.00
     15       20.00       0.83      10.20      58.00     122.00      64.00      17.00
     16       26.00       0.69      11.20      72.00     119.00      62.00      17.00
     17       16.00       0.76      10.00      51.00     113.00      65.00      18.00
     18       20.00       0.84       9.00      77.00     125.00      72.00      22.00
     19       32.00       0.80      11.20      55.00     124.00      63.00      15.00
     20       14.00       0.59       7.20      68.00     120.00      74.00       9.00
     21       11.00       0.51       6.60      78.00     129.00      80.00      13.00
     22        9.00       0.41       5.60      60.00     130.00      77.00      10.00
     23       21.00       0.89      11.00      52.00     133.00      63.00      19.00
     24       11.00       0.47       5.60      59.00     112.00      81.00      11.00
     25       18.00       0.83      16.20      50.00     128.00      63.00      15.00
     26       14.00       0.66       8.20      61.00     154.00      78.00      12.00
     27       17.00       0.58       6.20      68.00     134.00      76.00      16.00
     28       11.00       0.46       8.46      56.00     137.00      70.00       8.00
     29       16.00       0.62       7.00      74.00     121.00      71.00       9.00
     30       14.00       0.77       9.80      68.00     145.00      88.00      15.00
     31       16.00       0.75      10.60      58.00     131.00      82.00      13.00
     32       17.00       0.69      10.00      73.00     135.00      81.00      18.00
     33
     34       18.00       0.70       8.20      72.00     146.00      81.00       9.00
     35       13.00       0.63       8.20      77.00     126.00      75.00      12.00
     36       15.00       0.65       7.80      86.00     136.00      88.00      15.00
     37       13.00       0.64       9.20      55.00     130.00      87.00      12.00
     38       13.00       0.55       6.60      52.00     140.00      84.00      12.00
     39       10.00       0.39       7.20      63.00     131.00      93.00       7.00
     40       12.00       0.54      11.20      61.00     126.00      74.00      12.00

          Col( 22)s2pka
          Col( 23)s2pkv
          Col( 24)s2svi
          Col( 25)s2hr
          Col( 26)s2sbp
          Col( 27)s2dbp
          Col( 28)dpka
```

```
------------------------------------NCSS------------------------------------
Date:               01-01-1980
Time:               01:01:55
Data Base Name:     EXAMPLE
Description:
Backup of   Repeated measures two-way anova for thesis


Column:          29        30        31        32        33

       1       1.06     16.80     70.00    122.00     62.00
       2       0.62      7.60     56.00    127.00     79.00
       3       0.58      7.80     68.00    106.00     65.00
       4       0.54      6.20     50.00    114.00     55.00
       5       0.42      5.20     47.00    135.00     70.00
       6       0.78     12.80     72.00    118.00     82.00
       7       0.69     13.60     48.00    120.00     57.00
       8       0.61     12.00     51.00    120.00     58.00
       9       0.65     15.00     53.00    127.00     63.00
      10       0.52      7.20     65.00    120.00     63.00
      11       0.50      9.80     56.00    104.00     69.00
      12       0.59      9.40     63.00    132.00     68.00
      13       0.85     12.80     45.00    129.00     64.00
      14       0.66      9.00     59.00    119.00     69.00
      15       0.65      8.40     54.00    114.00     63.00
      16       0.66     12.00     72.00    111.00     57.00
      17       0.87     11.40     55.00    123.00     65.00
      18       0.94      9.20     72.00    122.00     82.00
      19       0.57      8.40     55.00    132.00     69.00
      20       0.38      7.20     75.00    115.00     67.00
      21       0.56      7.00     72.00    124.00     80.00
      22       0.42      5.80     55.00    127.00     81.00
      23       0.78      9.00     53.00    138.00     78.00
      24       0.49      5.80     52.00    127.00     82.00
      25       0.71     13.60     52.00    128.00     71.00
      26       0.59      8.00     60.00    152.00     82.00
      27       0.42      5.80     65.00    158.00     90.00
      28       0.29      9.00     58.00    129.00     74.00
      29       0.27      4.80     74.00    138.00     71.00
      30       0.76     10.80     60.00    152.00     88.00
      31       0.66     10.26     56.00    132.00     80.00
      32       0.75     10.20     70.00    140.00     87.00
      33
      34       0.31      5.40     76.00    149.00     89.00
      35       0.57      7.00     78.00    144.00     86.00
      36       0.58      6.80     88.00    130.00     83.00
      37       0.58      8.80     63.00    128.00     79.00
      38       0.50      5.80     51.00    134.00     85.00
      39       0.27      3.80     60.00    133.00     88.00
      40       0.50     10.80     61.00    128.00     70.00

           Col( 29)dpkv
           Col( 30)dsvi
           Col( 31)dhr
           Col( 32)dsbp
           Col( 33)ddbp
```

```
-----------------------------------NCSS-------------------------------------
Date:               01-01-1980
Time:               01:01:55
Data Base Name:     EXAMPLE
Description:
Backup of   Repeated measures two-way anova for thesis


Column:           29         30         31         32         33

      1         1.06      16.80      70.00     122.00      62.00
      2         0.62       7.60      56.00     127.00      79.00
      3         0.58       7.80      68.00     106.00      65.00
      4         0.54       6.20      50.00     114.00      55.00
      5         0.42       5.20      47.00     135.00      70.00
      6         0.78      12.80      72.00     118.00      82.00
      7         0.69      13.60      48.00     120.00      57.00
      8         0.61      12.00      51.00     120.00      58.00
      9         0.65      15.00      53.00     127.00      63.00
     10         0.52       7.20      65.00     120.00      63.00
     11         0.50       9.80      56.00     104.00      69.00
     12         0.59       9.40      63.00     132.00      68.00
     13         0.85      12.80      45.00     129.00      64.00
     14         0.66       9.00      59.00     119.00      69.00
     15         0.65       8.40      54.00     114.00      63.00
     16         0.66      12.00      72.00     111.00      57.00
     17         0.87      11.40      55.00     123.00      65.00
     18         0.94       9.20      72.00     122.00      82.00
     19         0.57       8.40      55.00     132.00      69.00
     20         0.38       7.20      75.00     115.00      67.00
     21         0.56       7.00      72.00     124.00      80.00
     22         0.42       5.80      55.00     127.00      81.00
     23         0.78       9.00      53.00     138.00      78.00
     24         0.49       5.80      52.00     127.00      82.00
     25         0.71      13.60      52.00     128.00      71.00
     26         0.59       8.00      60.00     152.00      82.00
     27         0.42       5.80      65.00     158.00      90.00
     28         0.29       9.00      58.00     129.00      74.00
     29         0.27       4.80      74.00     138.00      71.00
     30         0.76      10.80      60.00     152.00      88.00
     31         0.66      10.26      56.00     132.00      80.00
     32         0.75      10.20      70.00     140.00      87.00
     33
     34         0.31       5.40      76.00     149.00      89.00
     35         0.57       7.00      78.00     144.00      86.00
     36         0.58       6.80      88.00     130.00      83.00
     37         0.58       8.80      63.00     128.00      79.00
     38         0.50       5.80      51.00     134.00      85.00
     39         0.27       3.80      60.00     133.00      88.00
     40         0.50      10.80      61.00     128.00      70.00


          Col( 29)dpkv
          Col( 30)dsvi
          Col( 31)dhr
          Col( 32)dsbp
          Col( 33)ddbp
```

APPENDIX F
STATISTICAL TABLES

```
-----------------------------------NCSS-----------------------------------
Date:                  01-01-1980
Time:                  00:49:40
Data Base Name:        BODYMASS
Description:
t-test for body mass index

Column:            1          2

      1       23.70      23.30
      2       25.70      23.30
      3       25.30      22.70
      4       22.10      26.10
      5       25.70      26.30
      6       31.70      23.00
      7       26.70      33.10
      8       25.20      29.60
      9       23.40      26.60
     10       29.10      25.60
     11       23.10      24.30
     12       27.60      23.50
     13       29.20      23.30
     14       22.60      33.30
     15       24.00      30.30
     16       32.10      31.20
     17       25.00      30.00
     18       21.80      26.50
     19       25.60      33.50
     20       26.10      27.50

          Col(   1)NTNs
          Col(   2)BDL-HTN
```

```
-------------------------------------NCSS-------------------------------------
Date:                03-02-1989
Time:                01:41:06
Data Base Name:      SVICHANG
Description:
Correlation of change in SVI and Diastolic BP.

Column:              1          2

      1          37.00      38.00
      2          10.00     -17.00
      3          24.00       4.00
      4           7.00      16.00
      5         -11.00       7.00
      6          42.00       1.00
      7          86.00       3.00
      8          62.00      30.00
      9          43.00     -38.00
     10         152.00      39.00
     11         124.00       8.00
     12          36.00     -15.00
     13           9.00
     14          25.00     -26.00
     15         -40.00      53.00
     16           9.00      11.00
     17          28.00       6.00
     18          40.00       0.00
     19         -14.00      27.00
     20          37.00      29.00

          Col(   1)NTN Sum
          Col(   2)BDL-HTN sum
```

```
----------------------------Repeated Measures ANOVA----------------------------
Date:               01-01-1980
Time:               01:06:24
Data Base Name:     EXAMPLE
Description:
Backup of    Repeated measures two-way anova for thesis


                                  Anova Table

Source     D.F.   Sum-Squares      Mean-Squares   F-ratio          Prob)F

A           1      99.59433         99.59433       4.04             .049
S(A)        37     913.1578         24.67994
B           4      106.7242         26.68104       15.8             0
AB          4      27.05971         6.764927       4.01             .004
Error       148    249.8724         1.688327
Adj.Tot     194    1396.408         7.197982


Means and Counts

Overall Mean   :               8.875448
Overall Count  :               195

Factor A -- Column : 2  grp
Level      Count      Mean
 1          100        9.572002
 2          95         8.142231

Factor B
Level      Column     Count      Mean
 1          9          39         7.923076             stsvi
 2          12         39         9.799998             s1svi
 3          18         39         8.14359              usvi
 4          24         39         9.529643             s2svi
 5          30         39         8.980921             dsvi

Two-way Means ... Factor A, Factor B

Levels     Count      Mean

 1    1     20         7.97
 1    2     20         10.66
 1    3     20         8.74
 1    4     20         10.4
 1    5     20         10.09
 2    1     19         7.873684
 2    2     19         8.894737
 2    3     19         7.51579
 2    4     19         8.613473
 2    5     19         7.813474
```

```
-
-----------------------------Repeated Measures ANOVA-----------------------------
Date:               01-01-1980
Time:               01:07:41
Data Base Name:     EXAMPLE
Description:
Backup of    Repeated measures two-way anova for thesis

                                Anova Table

Source     D.F.   Sum-Squares       Mean-Squares     F-ratio         Prob>F

A          1       286.9219          286.9219         5.35            .025
S(A)       37      1984.217          53.62748
B          4       207.7231          51.93077         6.47            0
AB         4       24.20116          6.050291         .75             .562
Error      148     1187.276          8.022135
Adj.Tot    194     3690.339          19.02237

Means and Counts

Overall Mean   :               14.90769
Overall Count  :               195

Factor A -- Column : 2  grp
Level     Count      Mean
 1         100        16.09
 2         95         13.66316

Factor B
Level     Column     Count     Mean
 1         7          39        14.48718              stpka
 2         10         39        16.46154              s1pka
 3         16         39        13.87179              upka
 4         22         39        15.76923              s2pka
 5         28         39        13.94872              dpka

Two-way Means ... Factor A, Factor B

Levels     Count       Mean

 1    1     20          15.2
 1    2     20          17.95
 1    3     20          14.7
 1    4     20          17.3
 1    5     20          15.3
 2    1     19          13.73684
 2    2     19          14.89474
 2    3     19          13
 2    4     19          14.1579
 2    5     19          12.52632
```

```
-
---------------------------Repeated Measures ANOVA----------------------------
Date:               01-01-1980
Time:               01:08:23
Data Base Name:     EXAMPLE
Description:
Backup of   Repeated measures two-way anova for thesis


                                    Anova Table

Source    D.F.   Sum-Squares      Mean-Squares    F-ratio         Prob)F

A         1      .3029335          .3029335        3.86            .054
S(A)      37     2.903766          7.848016E-02
B         4      .2321354          5.803385E-02    7.36            0
AB        4      5.709584E-02      1.427396E-02    1.81            .129
Error     148    1.166769          7.883574E-03
Adj.Tot   194    4.6627            2.403453E-02


Means and Counts

Overall Mean  :               .6392822
Overall Count :               195

Factor A -- Column : 2  grp
Level     Count      Mean
 1         100        .6776999
 2         95         .5988421

Factor B
Level     Column     Count      Mean
 1         8          39         .6297435          stpkv
 2         11         39         .6889743          s1pkv
 3         17         39         .6166666          upkv
 4         23         39         .6674359          s2pkv
 5         29         39         .5935897          dpkv

Two-way Means ... Factor A, Factor B

Levels    Count      Mean

 1    1     20        .643
 1    2     20        .7265
 1    3     20        .6474999
 1    4     20        .7145
 1    5     20        .657
 2    1     19        .6157895
 2    2     19        .6494737
 2    3     19        .5842106
 2    4     19        .6178948
 2    5     19        .5268421
```

```
----------------------------Repeated Measures ANOVA----------------------------
Date:               01-01-1980
Time:               01:09:46
Data Base Name:     EXAMPLE
Description:
Backup of    Repeated measures two-way anova for thesis

                                 Anova Table

Source    D.F.   Sum-Squares       Mean-Squares    F-ratio         Prob)F

A         1       767.6875          767.6875        1.94            .169
S(A)      37      14663.79          396.3186
B         3       1096.436          365.4785        25.46           0
AB        3       88.393            29.46433        2.05            .11
Error     111     1593.671          14.35739
Adj.Tot   155     18209.97          117.4837


Means and Counts

Overall Mean  :                 63.98718
Overall Count :                 156

Factor A -- Column : 2  grp
Level     Count      Mean
 1         80         61.825
 2         76         66.26316

Factor B
Level     Column     Count      Mean
 1         13         39         64.02564            s1hr
 2         19         39         68.25641            uhr
 3         25         39         62.38462            s2hr
 4         31         39         61.28205            dhr

Two-way Means ... Factor A, Factor B

Levels    Count      Mean

 1   1     20         60.65
 1   2     20         66.85
 1   3     20         60.5
 1   4     20         59.3
 2   1     19         67.57895
 2   2     19         69.73684
 2   3     19         64.36842
 2   4     19         63.36842
```

```
----------------------------Repeated Measures ANOVA----------------------------
Date:               01-01-1980
Time:               01:10:23
Data Base Name:     EXAMPLE
Description:
Backup of   Repeated measures two-way anova for thesis

                                  Anova Table

Source     D.F.   Sum-Squares       Mean-Squares    F-ratio          Prob)F

A          1       10278.34          10278.34        43.69           0
S(A)       37      8704.432          235.2549
B          3       165.1538          55.05128        1.63            .185
AB         3       132.2778          44.09259        1.31            .274
Error      111     3739.569          33.68981
Adj.Tot    155     23019.77          148.5146


Means and Counts

Overall Mean  :               126.9615
Overall Count :               156

Factor A -- Column : 2  grp
Level      Count      Mean
 1          80         119.05
 2          76         135.2895

Factor B
Level      Column     Count      Mean
 1          14         39          125.9487          s1sbp
 2          20         39          127.7179          usbp
 3          26         39          125.9487          s2sbp
 4          32         39          128.2308          dsbp

Two-way Means ... Factor A, Factor B

Levels     Count      Mean

 1    1     20         117
 1    2     20         119.3
 1    3     20         119.4
 1    4     20         120.5
 2    1     19         135.3684
 2    2     19         136.5789
 2    3     19         132.8421
 2    4     19         136.3684
```

```
-
--------------------------Repeated Measures ANOVA---------------------------
Date:                01-01-1980
Time:                01:10:59
Data Base Name:      EXAMPLE
Description:
Backup of   Repeated measures two-way anova for thesis

                                   Anova Table

Source     D.F.   Sum-Squares      Mean-Squares    F-ratio        Prob>F

A           1      8331.001         8331.001        49.97           0
S(A)       37      6168.243         166.7093
B           3      446.9935         148.9978        8.66            0
AB          3      24.08596         8.028652        .47            .618
Error      111     1910.671         17.21325
Adj.Tot    155     16880.99         108.9096


Means and Counts

Overall Mean  :                 73.66026
Overall Count :                 156

Factor A -- Column : 2  grp
Level     Count       Mean
 1         80          66.5375
 2         76          81.1579

Factor B
Level     Column      Count      Mean
 1         15          39         73.4359            s1dbp
 2         21          39         76.17949           udbp
 3         27          39         71.41026           s2dbp
 4         33          39         73.61539           ddbp

Two-way Means ... Factor A, Factor B

Levels     Count       Mean

 1    1     20          65.75
 1    2     20.         69.4
 1    3     20          64.65
 1    4     20          66.35
 2    1     19          81.52631
 2    2     19          83.31579
 2    3     19          78.52631
 2    4     19          81.26316
```

```
--------------------------------T-Test Results--------------------------------
Date:             01-01-1980
Time:             00:53:33
Data Base Name:   BODYMASS
Description:
t-test for body mass index


         Unpaired T-Test Results

Column   1 has the label: NTNs
Column   2 has the label: BDL-HTN

Column   Sample                Std. Dev.      Mean
         Size
 1        20                    2.929213       25.785
 2        20                    3.713489       27.15

Mean difference :                             -1.365
Pooled std. error :                            1.057598
t statistic :                                 -1.29066
Right-tail probability :                      0.898
Two-tail   probability :                      0.205
F for equality of variances :                  1.607172
```

```
-
---------------------------Univariate Statistics----------------------------
Date:               01-01-1980
Time:               01:30:30
Data Base Name:     NORMALS
Description:
data for normotensives in thesis

                    Univariate Statistics

Column (  3)  Label: age

Mean - Average            26.75      Number of Observations    20
Standard Deviation        6.290134   Number of Missing Values  0
Coefficient of Variation  .2351452   Sum of weights            20

Variance                  39.56579   Sum of observations       535
Standard Error of Mean    1.406517   Adjusted Sum of Squares   751.75
T-Value Testing Mean=0    19.01861   Adjusted Sum of Cubes     6703.125

100-%tile (Maximum)       43         Adjusted Sum of Quartics  112078.1
 90-%tile                 37.5       Coefficient of Skewness   .3252125
 75-%tile                 27.5       Coefficient of Kurtosis   .1983234

 50-%tile (Median)        24.5       Range                     22
 25-%tile                 23         Inner Quartile Range      4.5
 10-%tile                 21
  0-%tile (Minimum)       21


                    Frequency Distribution

Group Freq %Freq Cum.Freq. %Cum.Freq. Midpoint    Histogram
  1     8  40.0      8        40.0     22.10E+00 :********
  2     4  20.0     12        60.0     24.30E+00 :****
  3     3  15.0     15        75.0     26.50E+00 :***
  4     1   5.0     16        80.0     28.70E+00 :*
  5     0   0.0     16        80.0     30.90E+00 :
  6     1   5.0     17        85.0     33.10E+00 :*
  7     1   5.0     18        90.0     35.30E+00 :*
  8     0   0.0     18        90.0     37.50E+00 :
  9     1   5.0     19        95.0     39.70E+00 :*
 10     1   5.0     20       100.0     41.90E+00 :*
```

```
-
---------------------------Univariate Statistics------------------------------
Date:                 01-01-1980
Time:                 01:30:51
Data Base Name:       NORMALS
Description:
data for normotensives in thesis

                       Univariate Statistics

Column (  4)  Label: ht

Mean - Average              175.51         Number of Observations     20
Standard Deviation          7.310188       Number of Missing Values   0
Coefficient of Variation    4.165112E-02   Sum of weights             20

Variance                    53.43884       Sum of observations        3510.2
Standard Error of Mean      1.634608       Adjusted Sum of Squares    1015.338
T-Value Testing Mean=0      107.3713       Adjusted Sum of Cubes      1936.288

100-%tile (Maximum)         192            Adjusted Sum of Quartics   142812
 90-%tile                   184.25         Coefficient of Skewness    .0598486
 75-%tile                   180            Coefficient of Kurtosis    .1385299

 50-%tile (Median)          175.5          Range                      28
 25-%tile                   170.6          Inner Quartile Range       9.399994
 10-%tile                   164
  0-%tile (Minimum)         164


                      Frequency Distribution

Group Freq  %Freq Cum.Freq. %Cum.Freq. Midpoint    Histogram
  1     3   15.0      3        15.0    16.54E+01 :***
  2     0    0.0      3        15.0    16.82E+01 :
  3     4   20.0      7        35.0    17.10E+01 :****
  4     3   15.0     10        50.0    17.38E+01 :***
  5     2   10.0     12        60.0    17.66E+01 :**
  6     4   20.0     16        80.0    17.94E+01 :****
  7     2   10.0     18        90.0    18.22E+01 :**
  8     0    0.0     18        90.0    18.50E+01 :
  9     1    5.0     19        95.0    18.78E+01 :*
 10     1    5.0     20       100.0    19.06E+01 :*
```

```
------------------------------Univariate Statistics------------------------------
Date:               01-01-1980
Time:               01:31:13
Data Base Name:     NORMALS
Description:
data for normotensives in thesis

                          Univariate Statistics

Column (  5)  Label: wt

Mean - Average              79.055        Number of Observations      20
Standard Deviation          10.05859      Number of Missing Values    0
Coefficient of Variation    .1272353      Sum of weights              20

Variance                    101.1752      Sum of observations         1581.1
Standard Error of Mean      2.249169      Adjusted Sum of Squares     1922.329
T-Value Testing Mean=0      35.14854      Adjusted Sum of Cubes       8528.443

100-%tile (Maximum)         99.5          Adjusted Sum of Quartics    423921.7
 90-%tile                   94.5          Coefficient of Skewness     .1011878
 75-%tile                   85.05         Coefficient of Kurtosis     .1147176

 50-%tile (Median)          77.85         Range                       34.5
 25-%tile                   71            Inner Quartile Range        14.05
 10-%tile                   65.3
  0-%tile (Minimum)         65


                        Frequency Distribution

Group Freq %Freq Cum.Freq.  %Cum.Freq.  Midpoint     Histogram
  1     3   15.0     3         15.0     66.72E+00 :***
  2     2   10.0     5         25.0     70.18E+00 :**
  3     3   15.0     8         40.0     73.63E+00 :***
  4     3   15.0    11         55.0     77.07E+00 :***
  5     3   15.0    14         70.0     80.53E+00 :***
  6     2   10.0    16         80.0     83.97E+00 :**
  7     0    0.0    16         80.0     87.43E+00 :
  8     1    5.0    17         85.0     90.88E+00 :*
  9     2   10.0    19         95.0     94.32E+00 :**
 10     1    5.0    20        100.0     97.78E+00 :*
```

```
-
----------------------------Univariate Statistics------------------------------
Date:                  01-01-1980
Time:                  01:31:28
Data Base Name:        NORMALS
Description:
data for normotensives in thesis

                        Univariate Statistics

Column (  6)  Label: bf

Mean - Average             11.28        Number of Observations    20
Standard Deviation         3.616715     Number of Missing Values  0
Coefficient of Variation   .3206308     Sum of weights            20

Variance                   13.08063     Sum of observations       225.6
Standard Error of Mean     .8087222     Adjusted Sum of Squares   248.532
T-Value Testing Mean=0     13.94793     Adjusted Sum of Cubes     116.7761

100-%tile (Maximum)        18           Adjusted Sum of Quartics  6293.584
 90-%tile                  15.75        Coefficient of Skewness   .0298044
 75-%tile                  14.85        Coefficient of Kurtosis   .1018904

 50-%tile (Median)         10.5         Range                     13.4
 25-%tile                  8.2          Inner Quartile Range      6.650001
 10-%tile                  6.8
  0-%tile (Minimum)        4.6


                        Frequency Distribution

Group  Freq  %Freq  Cum.Freq.  %Cum.Freq.  Midpoint     Histogram
  1      1    5.0       1          5.0     52.70E-01  :*
  2      1    5.0       2         10.0     66.10E-01  :*
  3      4   20.0       6         30.0     79.50E-01  :****
  4      2   10.0       8         40.0     92.90E-01  :**
  5      4   20.0      12         60.0     10.63E+00  :****
  6      0    0.0      12         60.0     11.97E+00  :
  7      2   10.0      14         70.0     13.31E+00  :**
  8      3   15.0      17         85.0     14.65E+00  :***
  9      2   10.0      19         95.0     15.99E+00  :**
 10      1    5.0      20        100.0     17.33E+00  :*
```

```
----------------------------Univariate Statistics----------------------------
Date:                 01-01-1980
Time:                 01:48:12
Data Base Name:       HYPERTEN
Description:
hypertensives in thesis

                      Univariate Statistics

Column (  3)  Label: age

Mean - Average              25.15789     Number of Observations    20
Standard Deviation          6.076029     Number of Missing Values  1
Coefficient of Variation    .2415158     Sum of weights            19

Variance                    36.91813     Sum of observations       478
Standard Error of Mean      1.393937     Adjusted Sum of Squares   664.5263
T-Value Testing Mean=0      18.04809     Adjusted Sum of Cubes     10020.15

100-%tile (Maximum)         47           Adjusted Sum of Quartics  231069.1
 90-%tile                   29           Coefficient of Skewness   .5849327
 75-%tile                   28           Coefficient of Kurtosis   .5232599

 50-%tile (Median)          23           Range                     28
 25-%tile                   22           Inner Quartile Range      6
 10-%tile                   21
  0-%tile (Minimum)         19


                      Frequency Distribution

Group  Freq  %Freq  Cum.Freq.  %Cum.Freq.  Midpoint     Histogram
  1      4   21.1       4         21.1     20.40E+00  :****
  2      7   36.8      11         57.9     23.20E+00  :*******
  3      3   15.8      14         73.7     26.00E+00  :***
  4      4   21.1      18         94.7     28.80E+00  :****
  5      0    0.0      18         94.7     31.60E+00  :
  6      0    0.0      18         94.7     34.40E+00  :
  7      0    0.0      18         94.7     37.20E+00  :
  8      0    0.0      18         94.7     40.00E+00  :
  9      0    0.0      18         94.7     42.80E+00  :
 10      1    5.3      19        100.0     45.60E+00  :*
```

```
----------------------------Univariate Statistics----------------------------
Date:              01-01-1980
Time:              01:48:27
Data Base Name:    HYPERTEN
Description:
hypertensives in thesis

                    Univariate Statistics

Column (  4)  Label: ht

Mean - Average             181.9737        Number of Observations    20
Standard Deviation         6.820056        Number of Missing Values  1
Coefficient of Variation   3.747825E-02    Sum of weights            19

Variance                   46.51316        Sum of observations       3457.5
Standard Error of Mean     1.564628        Adjusted Sum of Squares   837.2368
T-Value Testing Mean=0     116.3047        Adjusted Sum of Cubes     1833.723

100-%tile (Maximum)        198             Adjusted Sum of Quartics  106809.6
 90-%tile                  189             Coefficient of Skewness   7.569397E-02
 75-%tile                  187             Coefficient of Kurtosis   .152375

 50-%tile (Median)         180             Range                     27
 25-%tile                  178             Inner Quartile Range      9
 10-%tile                  172
  0-%tile (Minimum)        171


                   Frequency Distribution

Group Freq %Freq Cum.Freq. %Cum.Freq. Midpoint    Histogram
  1      3  15.8     3         15.8    17.24E+01 :***
  2      0   0.0     3         15.8    17.51E+01 :
  3      5  26.3     8         42.1    17.78E+01 :*****
  4      2  10.5    10         52.6    18.04E+01 :**
  5      1   5.3    11         57.9    18.31E+01 :*
  6      4  21.1    15         78.9    18.59E+01 :****
  7      3  15.8    18         94.7    18.86E+01 :***
  8      0   0.0    18         94.7    19.13E+01 :
  9      0   0.0    18         94.7    19.39E+01 :
 10      1   5.3    19        100.0    19.66E+01 :*
```

```
----------------------------Univariate Statistics----------------------------
Date:               03-02-1989
Time:               01:00:29
Data Base Name:     HYPERTEN
Description:
hypertensives in thesis

                    Univariate Statistics

Column (  5)  Label: wt

Mean - Average            91.20526      Number of Observations    20
Standard Deviation        14.23402      Number of Missing Values  1
Coefficient of Variation  .1560657      Sum of weights            19

Variance                  202.6072      Sum of observations       1732.9
Standard Error of Mean    3.265507      Adjusted Sum of Squares   3646.929
T-Value Testing Mean=0    27.92989      Adjusted Sum of Cubes     13851.16

100-%tile (Maximum)       116.5         Adjusted Sum of Quartics  1354947
 90-%tile                 111.75        Coefficient of Skewness   6.289194E-02
 75-%tile                 100.7         Coefficient of Kurtosis   .101875

 50-%tile (Median)        92.5          Range                     46.5
 25-%tile                 80            Inner Quartile Range      20.7
 10-%tile                 72.7
  0-%tile (Minimum)       70


                    Frequency Distribution

Group Freq %Freq Cum.Freq. %Cum.Freq. Midpoint    Histogram
  1      2  10.5      2        10.5    72.32E+00 :**
  2      2  10.5      4        21.1    76.97E+00 :**
  3      5  26.3      9        47.4    81.63E+00 :*****
  4      0   0.0      9        47.4    86.28E+00 :
  5      1   5.3     10        52.6    90.93E+00 :*
  6      2  10.5     12        63.2    95.57E+00 :**
  7      3  15.8     15        78.9    10.02E+01 :***
  8      1   5.3     16        84.2    10.49E+01 :*
  9      1   5.3     17        89.5    10.95E+01 :*
 10      2  10.5     19       100.0    11.42E+01 :**
```

```
------------------------------Univariate Statistics-----------------------------
Date:                 01-01-1980
Time:                 01:49:12
Data Base Name:       HYPERTEN
Description:
hypertensives in thesis

                    Univariate Statistics

Column (  6)  Label: bf

Mean - Average               13.45789     Number of Observations    20
Standard Deviation           5.130445     Number of Missing Values  1
Coefficient of Variation     .3812219     Sum of weights            19

Variance                     26.32146     Sum of observations       255.7
Standard Error of Mean       1.177005     Adjusted Sum of Squares   473.7863
T-Value Testing Mean=0       11.43402     Adjusted Sum of Cubes     3253.388

100-%tile (Maximum)          28.4         Adjusted Sum of Quartics  56725.54
 90-%tile                    19.65        Coefficient of Skewness   .3154729
 75-%tile                    16.7         Coefficient of Kurtosis   .2527049

 50-%tile (Median)           12.1         Range                     21.9
 25-%tile                    10.2         Inner Quartile Range      6.500001
 10-%tile                    9.3
  0-%tile (Minimum)          6.5


                    Frequency Distribution

Group Freq %Freq Cum.Freq. %Cum.Freq. Midpoint   Histogram
  1     1   5.3      1        5.3     75.95E-01 :*
  2     8  42.1      9       47.4     97.85E-01 :********
  3     3  15.8     12       63.2     11.98E+00 :***
  4     1   5.3     13       68.4     14.17E+00 :*
  5     3  15.8     16       84.2     16.35E+00 :***
  6     1   5.3     17       89.5     18.55E+00 :*
  7     1   5.3     18       94.7     20.74E+00 :*
  8     0   0.0     18       94.7     22.93E+00 :
  9     0   0.0     18       94.7     25.11E+00 :
 10     1   5.3     19      100.0     27.31E+00 :*
```

```
-
-------------------------------T-Test Results--------------------------------
Date:               01-01-1980
Time:               02:24:01
Data Base Name:     TABLES
Description:
Normals 1st 33 columns, hypers the rest


         Unpaired T-Test Results

Column   3 has the label: age
Column  36 has the label: age

Column   Sample               Std. Dev.      Mean
         Size
 3        20                   6.290134       26.75
 36       19                   6.076029       25.15789

Mean difference :                             1.592106
Pooled std. error :                           1.982046
t statistic :                                 .803264
Right-tail probability :                     0.213
Two-tail   probability :                     0.427
F for equality of variances :                 1.071717
```

```
-
-------------------------------T-Test Results--------------------------------
Date:             01-01-1980
Time:             02:24:33
Data Base Name:   TABLES
Description:
Normals 1st 33 columns, hypers the rest


         Unpaired T-Test Results

Column   4 has the label: ht
Column  37 has the label: ht

Column   Sample              Std. Dev.      Mean
         Size
 4        20                  7.310188       175.51
 37       19                  6.820056       181.9737

Mean difference :                           -6.463684
Pooled std. error :                          2.266875
t statistic :                               -2.851363
Right-tail probability :                    0.996
Two-tail   probability :                    0.007
F for equality of variances :                1.148897
```

```
--------------------------------T-Test Results--------------------------------
Date:              01-01-1980
Time:              02:24:59
Data Base Name:    TABLES
Description:
Normals 1st 33 columns, hypers the rest


         Unpaired T-Test Results

Column   5 has the label: wt
Column  38 has the label: wt

Column   Sample                Std. Dev.         Mean
         Size
 5        20                   10.05859          79.055
 38       19                   14.23402          91.20526

Mean difference :                                -12.15026
Pooled std. error :                               3.930414
t statistic :                                    -3.091343
Right-tail probability :                         0.998
Two-tail   probability :                         0.004
F for equality of variances :                     2.002538
```

```
-
------------------------------T-Test Results------------------------------
Date:                01-01-1980
Time:                02:25:33
Data Base Name:      TABLES
Description:
Normals 1st 33 columns, hypers the rest


         Unpaired T-Test Results

Column   6 has the label: bf
Column  39 has the label: bf

Column   Sample                Std. Dev.      Mean
         Size
 6        20                    3.616715       11.28
 39       19                    5.130445       13.45789

Mean difference :                             -2.177895
Pooled std. error :                            1.415481
t statistic :                                 -1.538625
Right-tail probability :                      0.934
Two-tail   probability :                      0.132
F for equality of variances :                  2.012247
```

```
----------------------------Correlation Analysis----------------------------
Date:              03-02-1989
Time:              01:41:57
Data Base Name:    SVICHANG
Description:
Correlation of change in SVI and Diastolic BP.


                              Correlation Analysis

                              Univariate Statistics

Column Label                        N       Mean          Standard Deviation
   1  NTN Sum                      20       35.3             44.87304
   2  BDL-HTN sum                  19       9.263158         23.33296

                              Correlations

Correlations with column 1   NTN Sum

Column Label                        N Correlation  R Squared   Prob |r|=0
  2     BDL-HTN sum                19  0.0004       0.0000       0.999

Correlations with column 2   BDL-HTN sum

Column Label                        N Correlation  R Squared   Prob |r|=0
  1     NTN Sum                    19  0.0004       0.0000       0.999
```

The vita has been removed from
the scanned document

CHANGES IN CW-DOPPLER AORTIC BLOOD FLOW RESPONSES WITH PASSIVE TILTING IN NORMO- AND BORDERLINE HYPERTENSIVE MEN

by

Ray William Morris

(ABSTRACT)

Continuous-wave (CW) Doppler echocardiographic responses to passive tilting were measured in 39 men using the following protocol: standing; supine; +20° head-up; supine; -20° head-down. Twenty of the subjects were normotensive (NTN) and the rest were borderline hypertensive (B-HTN) according to prior medical diagnosis. Doppler recordings of blood flow for aortic peak velocity (PkV), peak acceleration (PkA), and stroke velocity integral (SVI) were taken after 15 minutes in each posture. A skilled technician, using the measurement procedures recommended by the instrument manufacturer, positioned the hand-held probe at the supra-sternal notch during recording. For both NTN and B-HTN groups, PkV and PkA were unaffected by the imposed postural changes. The SVI was significantly altered ($P<0.05$) by postural stress, with the NTN group generally showing greater changes than the B-HTNs. The standing-to-supine postural change was associated with the largest change in SVI: NTN = 8.0 to 10.7 cm (+34%) and B-HTN = 7.6 to 8.8 cm (+15%). These results were interpreted as follows: (1) SVI appears to be sensitive to changes in ventricular pre-load, while PkA and PkV are not; (2)

SVI changes with passive tilting follow the patterns expected for change in ventricular stroke volume and; (3) attenuated SVI responses to postural tilting may suggest impairment in cardiovascular regulation peculiar to individuals at risk for hypertension.