CARDIOVASCULAR CIRCADIAN RHYTHMS IN NORMOTENSIVE AND HYPERTENSIVE ADOLESCENTS

A DISSERTATION
SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
IN THE GRADUATE SCHOOL OF THE
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COLLEGE OF NURSING

by

ANNE C. JACOBY, B.S.N., M.S.N., R.N.

DENTON, TEXAS

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TEXAS WOMAN'S UNIVERSITY
DENTON, TEXAS

4 April 1988
Date

To the Provost of the Graduate School:

I am submitting herewith a dissertation written by

Anne Catherine Jacoby

entitled Cardiovascular Circadian Rhythms in Normotensive and Hypertensive Adolescents

I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Nursing.

Margie N. Johnson

We have read this dissertation
and recommend its acceptance:

Peggy J. Drapo
Margaret T. Beard
Helen A. Bush
Glen Jennings

Accepted

Leslie M Thompson
Provost of the Graduate School

DEDICATION

This disseratation is dedicated to my husband Jon and children Melissa Anne and Matthew David; parents Bill and Arleen Michael; brothers Stephen and Douglas and sister Marsha; and friends and mentors Jeannene K. Boosinger R.N., Ph.D., Associate Professor of Nursing, University of Nebraska College of Nursing, Emeritus, and Rena E. Boyle R.N., Ph.D., Professor of Nursing, Dean, University of Nebraska College of Nursing, Emeritus.

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Finally, a very special appreciation to my family and friends for their caring and love. A goal becoming a reality means that much more because I'm able to share it

with them.

CARDIOVASCULAR CIRCADIAN RHYTHMS IN NORMOTENSIVE AND HYPERTENSIVE ADOLESCENTS

ABSTRACT

ANNE C. JACOBY, B.S.N., M.S.N., R.N.

TEXAS WOMAN'S UNIVERSITY
COLLEGE OF NURSING

MAY 1988

With the improvement in automatic instruments for obtaining cardiovascular measurements, the ability to identify circadian (24-hour) rhythmic patterns in normotensive/hypertensive adolescents is greatly enhanced.

The study's purposes were to: (a) quantify adolescent blood pressure and heart rate as reflected in circadian rhythmic patterning; (b) establish a scientific basis for continued nursing research in circadian rhythmicity; and (c) validate the SpaceLabs 90202 Ambulatory Blood Pressure Monitor.

After meeting specific delimitations, ten hypertensive students were matched for age, sex, and ethnicity with a stratified random normotensive group who had no family history of hypertension. For 24 hours, each student wore a SpaceLabs unit programmed to inflate the blood pressure cuff at specific intervals. An Activity Diary facilitated data interpretation.

Cosinor analysis was employed on edited blood pressure

and heart rate measurements. The mesor systolic blood pressure was significantly lower ($p \leq .010$ to .001) in the normotensive adolescent. A t-test revealed a significant difference in this parameter between the two groups (p = .0005, df = 13). A t-test also indicated a significant difference in systolic blood pressure amplitude between the normotensive/hypertensive students (p = .023, df = 13).

The SpaceLabs 90202 Monitor Validation Study revealed no significant differences in blood pressure readings when the unit's measurements were compared with either auscultatory (p = .001 and .05 for systolic and diastolic blood pressures respectively) or direct arterial measurements (p = .001 and .02 for systolic and diastolic blood pressures respectively).

While the findings reflect anticipated greater systolic blood pressure mesors and amplitudes in the hypertensive adolescent, such hypertensive / normotensive categories may be a misnomer since all individuals have a certain percentage of elevated pressures over a 24-hour period.

It is recommended that the study be repeated to: (a) further validate the SpaceLabs monitor; (b) collect data for a minimum of 48 hours with specific documentation as to why three or more monitor error codes were being consecutively generated; and (c) further contribute to a circadian cardiovascular data base which may yield additional infor-

mation about the complex factors modulating adolescent blood pressure.

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CHAPTER I

INTRODUCTION

Chronobiology, of which circadian (24-hour) rhythmicity is a component, is an emerging science offering a unique rhythmometric perspective of life. Rhythms with different frequencies are found at all levels of biologic integration... (Halberg, Johnson, Nelson, Runge, & Sothern, 1972). In the case of human blood pressure, relatively dense measurement series have served to derive indices of these rhythms that can be readily computed, intuitively compared, and validated by inferential statistics (Halberg, Ahlgren, & Haus, 1984). Although these patterns are peculiar to each individual, there are similarities among subjects compared by age, sex, and living conditions.

With the advent of and improvement in automatic instruments for obtaining blood pressure and heart rate measurements, the ability to identify circadian rhythmic patterns in normotensive and hypertensive young people is now greatly enhanced. Understanding blood pressure fluctuations is: (a) an important component of nursing diagnosis (Rogers, 1983); and (b) fundamental in developing a dynamic nursing knowledge base for regulatory decision-making in prevention and health promotion.

Purposes

The study's purposes are three-fold:

1. To quantify adolescent blood pressure/heart rate diversity, complexity, and frequency as reflected in circadian rhythmic patterning and repatterning.

2. To establish a scientific basis for continued nursing research and theory development in circadian rhythmic patterns.

3. To validate the SpaceLabs 90202 Ambulatory Blood Pressure Monitor (SpaceLabs, Redmond, WA).

Problems of Study

The problem statement is "What are the similarities and/or differences in blood pressure and heart rate circadian rhythmic patterns between normotensive and hypertensive adolescents?"

The subquestions are:

1. What are the similarities and/or differences in blood pressure and heart rate level (mean or mesor), amplitude, and acrophase between normotensive and hypertensive adolescents?

2. What are the similarities and/or differences in blood pressure and heart rate circadian rhythmic coordination between normotensive and hypertensive adolescents?

3. Is there a relationship between circadian rhythm synchrony and blood pressure level?

4. What is the distribution of the circadian overall

hyperbaric index (HBI)?

5. How do the blood pressure measurements obtained by the recently developed SpaceLabs 90202 unit compare with those obtained via auscultation or direct arterial monitoring?

Justification of the Problem

High blood pressure afflicts an estimated 54,990,000 adults and 2,720,000 children ages six through 17 (American Heart Association, 1986). Two major objectives of childhood and adolescent blood pressure studies conducted over the past twenty years have been to: (a) examine the pattern of blood pressure change during various phases of growth; and (b) understand how these changes are related to the subsequent development of hypertension (Barón, Theyer, & Fixler, 1986). However, major problems persist in deciding how to determine normal blood pressure levels for young persons from birth to adulthood (Garbus, Garbus, Young, Hassinger, & Johnson, 1980). The reported levels of indirect blood pressure provided by numerous epidemiological studies vary considerably (Goldring, Londe, Sivakoff, Hernandez, Britton, & Choi, 1977; Hediger, Schall, Barker, Bowers, Gruskin, & Katz, 1981; Katz, Hediger, & Schall, 1980; Lackland, Riopel, Shepard, & Wheller, 1985; Lauer, Clarke, & Beaglehold, 1984; National Heart, Lung, & Blood Institute, 1978; Prineas, Gillum, Horibe, & Hannan, 1980; Voors,

Foster, Frericks, Webber, & Berenson, 1976; Voors, Webber, & Berenson, 1979.) The conflicting findings may be partially attributed to: (a) inconsistent study methodologies; and (b) inaccurate conclusions drawn from the incomplete data generated by casual blood pressure measurements.

Although it has been suggested that the diagnosis should be based on elevated blood pressures on a least two to three separate occasions, there are no criteria as to the time or duration during the 24 hours that the blood pressures must be elevated to substantiate the diagnosis (Berenson, 1986). With the advent of and improvement in automatic instruments for obtaining blood pressures, this cardiovascular parameter may now be monitored over a 24-hour period. While numerous studies have researched this noninvasive method of monitoring ambulatory blood pressure (Berglund, DeFaire, Castenfors, Andersson, Hartford, Liedholm, Ljungman, Thulin & Wikstrand, 1985; Corsi, Germano, Appoloni, Ciavarelli, De Zorzi, & Calcagnini, 1983; DiRienzo, Grassi, Pedotti, & Mancia, 1983; Drayer, Hoefnagels, & Kloppenbrog, 1976; Drayer, Weber, & DeYoung, 1983; Drayer & Weber, 1985; Drayer, Weber, & Nakamura, 1985; Floras, Hassan, Sever, Jones, Osikowska, & Sleight, 1981; Gould, Hornung, Cashman, Altman, & Raftery, 1986; Horan, Kennedy, & Padgett, 1981; Horan, Padgett, Kennedy, 1981; Horan, 1985; Kennedy, Horan, Sprague, Padgett, & Shriver,

1983; Mancia, 1983; Mancia, Ferrari, Gregorini, Parati, Pomidossi, Bertinieri, Grassi, Di Rienzo, Pedotti, & Zanchetti, 1983; Mann, Millar-Craig, & Raftery, 1985; Perloff & Sokolow, 1978; Pickering, Harshfield, Kleinert, Blank, & Laragh, 1982; Pickering, Harshfield, & Laragh, 1985; Wallace, 1979), nation-wide studies validating the SpaceLabs 90202 Ambulatory Blood Pressure Monitor are still ongoing.

Little research has been conducted in the area of adolescent cardiovascular circadian rhythmicity. Answers to these questions concerning this topic may facilitate identifying those individuals at risk to develop hypertension and the subsequent cardiovascular complications often associated with this disease/symptom. Understanding blood pressure fluctuations is also fundamental in developing a dynamic knowledge base for regulatory decision-making in prevention and health promotion.

Understanding the early natural history of hypertension has definite nursing implications, for an important component of nursing diagnosis is to identify sequential, cross-sectional patterning in the life process (Rogers, 1983). Just as this complex series of rhythmic cycles is integrated with environmental stimuli, each component cycle is integrated internally with all other rhythmic changes (Bassler, 1976). A multioscillator system promotes temporal

1983; Mancia, 1983; Mancia, Ferrari, Gregorini, Parati, Pomidossi, Bertinieri, Grassi, Di Rienzo, Pedotti, & Zanchetti, 1983; Mann, Millar-Craig, & Raftery, 1985; Perloff & Sokolow, 1978; Pickering, Harshfield, Kleinert, Blank, & Laragh, 1982; Pickering, Harshfield, & Laragh, 1985; Wallace, 1979), nation-wide studies validating the SpaceLabs 90202 Ambulatory Blood Pressure Monitor are still ongoing.

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order within the organism, keeping diverse rhythms in distinct phase relationships with one another as daily changes occur (Aschoff, Gericke, & Wever, 1967; Aschoff & Wever, 1976; Moore-Ede, Schmelzer, Kass, & Herd, 1976). Therefore, the major goals of professional nursing include: (a) promoting a symphonic interaction between man and environment; (b) strengthening the coherence and integrity of the human field; and (c) directing and redirecting patterning of the human and environmental fields for realization of maximum health potential (Rogers, 1983).

Theoretical Framework

Chronobiology

Chronobiology and Rogers' resonancy, helicy, and integrality principles dovetail to form the theoretical framework for this study investigating cardiovascular circadian rhythms in normotensive and hypertensive adolescents.

> Chronobiology is a branch of science objectively quantifying and investigating mechanisms of biologic time structure, including rhythmic manifestations of life. Rhythms with different frequencies are found at all levels of biologic integration - ecosystem, population, group, individual, organ-system, organ, tissue, cell and subcellular structure. Their ubiquity and their importance to the survival of both the individual and the species have prompted the development of a special methodology to study these temporal characteristics in the context of development, growth and aging.... In physiologic terms, chronobiology provides concepts and techniques for resolving predictable cycles in organisms and for isolating environmental effects from underlying endogenous mechanisms (Halberg et al, 1972, p.1).

The multioscillator system (biological clock) promotes temporal order within the organism, keeping diverse rhythms in distinct phase relationships with one another as daily changes occur (Aschoff et al., 1967; Moore-Ede et al., 1976). These rhythmic cycles are prompted (entrained) by external cues which help man maintain normal or near normal functioning patterns. Man's health is optimal when his circadian rhythms are synchronized with his life style and life cycle (Aschoff, 1965). Circadian rhythms refer to rhythms with frequencies of one cycle in 20 to 28 hours (Halberg, Katinas, Chiba, Garcia-Sanz, Kovats, Kunkel, Montabetti, Reinberg, Scharf, & Simpson, 1973). While the multiple oscillators are usually coupled to one another, their cycles or phase relationships can become dysynchronous under certain conditions.

These rhythms may be translated visually into a cosine curve (see Figure 1). The hours of the 24-hour clock form the horizontal axis and the magnitude of the measured variable is the vertical axis. A cosine curve is drawn to include the greatest number of points possible and is said to be the curve of best fit. In chronobiology, many terms are employed to discuss circadian rhythms. Terms used in this study are cycle, frequency, amplitude, acrophase, mesor, period, nadir, percent rhythm, synchronous,

dysynchronous, and zeitgeber.

A cycle is a recurrent pattern whose circular process starts from a point of origin and returns to the original point. The clock time required to complete one cycle is known as a period. It is conventionally described in terms of completion of a 360-degree circle in reference to an external measure such as clock time. Mesor is defined as

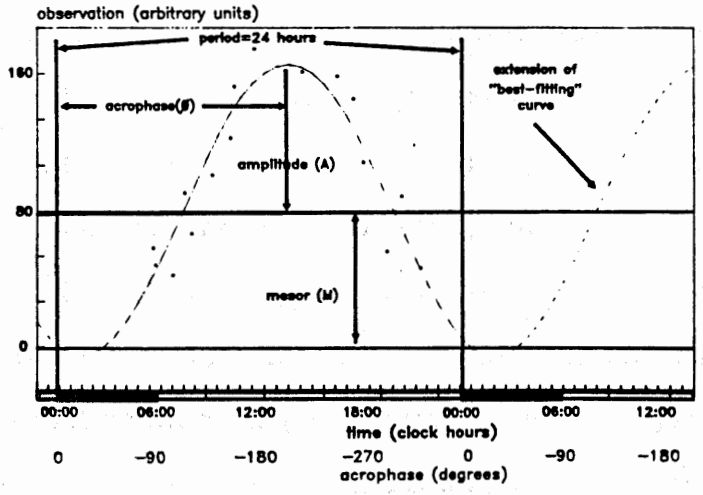

Figure1. Circadian Rhythmicity as Illustrated by the Cosine Curve of Best Fit.

the mean of the cosine curve fitted to a rhythmic variable (Hoskins, 1979). Amplitude is the magnitude of change or variation in a daily cycle. Within a cycle, an acrophase (peak) occurs which is the highest point of a complete, recurrent cycle. A nadir (trough) is the lowest point of that complete, recurrent cycle. The acrophase may shift in time and either advance or delay. A phase advance is a

negative shift and means that a rhythm peaks later in the 24-hour day. A phase delay is a positive shift and means that a rhythm peaks earlier in the day. A variable may even become completely uncoupled or dysynchronous. Percent rhythm describes how much of the data is explained by a fitted curve. It is not dependent upon the level of significance for that curve when compared to published norms for a particular variable. A high percent rhythm indicates that the variable is tightly coupled to its driving oscillator. Conversely, a lower percent rhythm indicates the variable to be more loosely coupled to its driving oscillator. The variable may even become completely uncoupled or dysynchronous. Dysynchronous refers to previously synchronous rhythms which no longer exhibit the same frequency and phase relationships. A zeitgeber is a synchronizing cue which influences circadian patterns; it synchronizes by determining phase. Alterations in internal and external cues may contribute to dysynchronization.

Rogers' Science of Unitary Human Beings

Within Rogers' (1983) theoretical framework, man and environment are defined as four-dimensional, negentropic energy fields identified by pattern and organization. Pattern and organization identify a human being and reflect innovative wholeness. Pattern recognition as a means of distinguishing individuals is an everyday

occurrence (Rogers, 1983).

> Patterning is a dynamic process.... Man's capacity to maintain himself while undergoing continuous change is a remarkable characteristic. This capacity is commonly referred to as man's self-regulating ability.... Efforts to identify self-regulatory mechanisms operating in man have revealed a range of physiological functioning (Rogers, 1983, pp. 62-63).

Self-regulation is identified with maintaining multiple functions in living systems and directed toward: (a) achieving increasing complexity of organization; and (b) fulfilling the potentialities of life (Rogers, 1983).

The previous statements reflect the Rogerian principles of helicy, resonancy, and integrality. Helicy refers to the increasing complexity and diversity of the human and environmental fields. Resonancy is concerned with the continuous change in wave patterns from lower to higher frequency (Rogers, 1983). The terms peak, trough, period, amplitude and cycle define resonancy's distinctive characteristics (Floyd, 1981). Integrality identifies the interaction between the human and environmental fields as a continuous, mutual, and simultaneous process (Rogers, 1985).

From these principles, the Theory of Accelerating Evolution was derived. It states that accelerating change is characterized by higher wave frequency pattern and organization (Malinski, 1986). In conclusion, Rogerian Theory and the Theory of Accelerating Evolution have

implications for understanding hypertension. It may be hypothesized that aging and higher blood pressure levels are characterized by waveform patterns with increasing diversity, complexity, and frequency. Furthermore, changes in humans' rhythmic repatterning are postulated to occur more rapidly in response to disruptions in person-environment interaction. It is, therefore, the responsibility of professional nursing practice to promote symphonic interaction between man and environment, to strengthen the coherence and integrity of the human field, and to direct and redirect patterning of the human and environmental fields for realization of maximum health potential (Rogers, 1983).

Assumptions

The following three assumptions are derived from circadian rhythmicity's theoretical rationale: (a) Man's health is optimal when his/her circadian rhythms are synchronized with his/her life style and life cycle (Aschoff, 1965); (b) There is a critical value above which an elevated pressure may potentiate tissue changes which will eventually lead to overt damage (Halberg et al., 1984); and (c) Rather than being static, the blood pressure critical value demonstrates its own rhythmicity. Rogers (1983) identifies five assumptions which underlie her holistic view of man and the four original principles of

reciprocy, synchrony, helicy, and resonancy (Gill & Atwood, 1981). Four of these assumptions are most applicable to this study and deal with whole man, man-environment interaction, and the space-time continuum:

1. Man is a unified whole possessing his own integrity and manifesting characteristics that are more than and different from the sum of his parts (Rogers, 1983, p.47).

2. Man and environment are continuously exchanging matter and energy with one another (Rogers, 1983, p. 54).

3. The life process evolves irreversibly and unidirectional along the space-time continuum (Rogers, 1983, p.59).

4. Pattern and organization identify man and reflect his innovative wholeness (Rogers, 1983, p.65).

Other assumptions reflecting Rogers' theoretical framework include:

5. "... health and illness are part of the same continuum (Rogers, 1983, p. 125)."

6. Blood pressure and heart rate rhythms represent two indexes of human field function.

7. Hypertension represents an arbitrary deviation in the rhythmic relationship between human beings and their environment.

Propositions

The four "building block" concepts of Rogers' theory

are energy fields, openness, four-dimensionality, and pattern and organization. From these concepts, the following propositions were derived:

1. Open systems (energy fields) interact with each other, displaying increasing diversity, complexity, and frequency of organization as they move unidirectional along an infinite space-time continuum. For this study, increasing blood pressure levels are reflected by increasing complexity, diversity, and frequency of circadian rhythmic patterning. As an individual ages along the space-time continuum, cardiovascular rhythmic patterns again become increasingly more complex, diverse, and frequent.

2. Since living things are always becoming more diverse as well as interacting with their environments, the pattern of their wave organization is also uniquely and constantly changing (Rogers, 1983). The study's hypotheses are derived primarily from this conceptualization.

Hypotheses

Chronobiology and Rogers'(1983) resonancy, helicy, and integrality principles provide the theoretical framework from which the following null hypotheses are formulated:

1. There are no significant differences in systolic/diastolic blood pressure mesors between normotensive and hypertensive adolescents.

2. There are no significant differences in heart rate

mesors between normotensive and hypertensive adolescents.

3. There are no significant differences in systolic/diastolic blood pressure amplitudes between normotensive and hypertensive adolescents.

4. There are no significant differences in heart rate amplitudes between normotensive and hypertensive adolescents.

5. As reflected by acrophase and mean percent rhythm, there are no significant differences in circadian rhythm synchrony between normotensive and hypertensive adolescents.

a. There are no significant differences in systolic diastolic blood pressure acrophases between normotensive and hypertensive adolescents.

b. There are no significant differences in heart rate acrophase between normotensive and hypertensive adolescents.

c. There are no significant differences in mean percent rhythms between normotensive and hypertensive adolescents.

6. There are no significant differences in overall circadian hyperbaric indices (HBI) between normotensive and hypertensive adolescents.

Definition of Terms

The following are the study's theoretical and operational definitions:

1. Circadian --

Theoretical/Operational -- a rhythm with a frequency of one cycle in a 20 to 28 hour period (Halberg et al.,1973). Only rhythms with this frequency are analyzed.

(a) mesor -- the mean of the cosine curve fitted to a rhythmic variable. This cardiovascular diversity provides a perspective of Rogers' helicy principle.

(b) amplitude -- the magnitude of change or variation in a daily life cycle and reflects Rogers' resonancy principle.

(c) acrophase -- the peak or highest point of a complete recurrent cycle and also illustrates the resonancy principle.

(d) overall hyperbaric index (HBI) -- for 24 hours, the integral of blood pressures above a fixed value (Halberg et al., 1984). The helicy principle again provides the definition's framework. Parameter excesses demonstrate greater diversity and complexity with the higher levels hypothesized to contribute to end target organ damage.

(e) mean percent rhythm -- describes how much of the data is explained by a fitted curve.

(f) synchrony -- circadian rhythms demonstrating identical frequency and phase relationships. Acrophase coordination and mean percent rhythm are indicators of circadian synchrony.

Cosinor analysis (Halberg, 1969) will calculate the best unbiased estimates of these parameters in addition to percent rhythm for each variable. It will also identify synchrony or dysynchrony among the rhythms. Specifically, the analysis will yield the variables' phase relationships with each other and with the predicted norms for each subject.

2. Hypertension --

Theoretical -- a cardiovascular rhythm repatterning secondary to alterations in the rhythmic relationship between man and his environment.

Operational -- during a screening program, a systolic and/or diastolic blood pressure measurement which is greater than the 90th percentile values of systolic/diastolic blood pressures for the appropriate age-sex category (Second Task Force on Blood Pressure Control in Children, 1986). These criteria must be met for two of two or two of three blood pressure screening measurements.

Table 1

Age Specific 90th Percentile Blood Pressure Measurements in Boys

Years	13	14	15	16	17	18
Systolic BP	124	126	129	131	124	136
Diastolic Bp	77	78	79	81	83	84
Height (cm)	165	172	178	182	184	184
Weight(kg)	62	68	74	80	84	86

Table 2

Age Specific 90th Percentile Blood Pressure Measurements in Girls

Years	13	14	15	16	17	18
Systolic BP	124	125	126	127	134	127
Diastolic Bp	78	81	82	81	80	80
Height (cm)	165	168	169	170	170	170
Weight(kg)	63	67	70	72	73	74

3. Normotension --

Theoretical -- a cardiovascular rhythmic pattern reflecting man's rhythmic relationship with his environment.

Operational -- during a screening program, a systolic and/or diastolic blood pressure measurement which is less than or equal to the 90th percentile values of systolic/diastolic blood pressures for the appropriate age-sex category (see Tables 1 & 2). If the subject meets these criteria, only one blood pressure measurement is taken.

4. Blood Pressure --

Theoretical -- a cardiovascular pattern interrelated with heart rate rhythmicity.

Operational -- the SpaceLabs 90202 Ambulatory Blood Pressure (ABP) unit obtains arterial pressures via the oscillometric method. As the cuff pressure descends in linear bleed steps, algorithms graph the oscillometric pulses over the entire range of cuff pressures. The shape of the resulting curve is employed to determine the subject's systolic, diastolic, and mean arterial pressures.

5. Heart rate --

Theoretical -- a cardiovascular pattern interrelated with blood pressure rhythmicity.

Operational -- The SpaceLabs 90202 unit also monitors heart rate in beats per minute via the previously mentioned oscillometric technique.

6. Adolescent --

Theoretical -- an individual moving unidirectional along that portion of the space-time continuum beginning with the onset of secondary sex characteristics to age 19. The maturational process is reflected by increasing complexity, diversity, and frequency in rhythmic patterns.

Operational -- for this study, the students between the ages of 13 and 19 years old (inclusive) who are enrolled in a large metropolitan health magnet school.

Limitations

The following limitations are identified:

1. A one-time screening blood pressure measurement for those students with normal blood pressure levels and no family history of hypertension.

2. Lack of validation of the SpaceLabs 90202 Ambulatory Blood Pressure(ABP) Monitor.

3. Loss of data secondary to lack of subject compliance, absolute or suspected artifact, and/or the need to temporarily remove the SpaceLabs unit.

4. The blood pressure monitor may have a novelty effect or interfere with sleep thereby temporarily altering circadian rhythmicity.

5. Undetected dysrhythmias.

6. Lack of control of extraneous factors/external cues or stimuli, i.e. physical activity, emotions, diet, medications, wake/sleep patterns, etc. (The use of drugs and alcohol were not addressed as honesty would be doubtful.)

Summary

Chronobiology and Rogers' resonancy, helicy, and integrality principles dovetail to form the theoretical framework for this study investigating cardiovascular circadian rhythms in normotensive and hypertensive adolescents. Although the theoretical and operational definitions are explicit, it is recognized that Rogers' helicy, resonancy, and integrality principles overlap. The study will analyze only circadian rhythms or those with frequencies of one cycle in 20 to 28 hours. Acrophase and amplitude reflect the Rogerian resonancy principle. Mesor indicates cardiovascular diversity while the HBI's parameter excesses demonstrate greater diversity and complexity with the higher levels hypothesized to contribute to end target organ damage. Rogers' helicy principle is reflected by the mesor and HBI. Acrophase coordination (resonancy) and mean percent rhythm illustrate circadian synchrony. Synchrony

refers to circadian rhythms demonstrating identical frequency and phase relationships.

The Theory of Accelerating Evolution contends that increasing blood pressure levels are characterized by waveform patterns with increasing diversity, complexity, and frequency. It is anticipated that the hypertensive adolescent is able to regulate these more diverse and complex cardiovascular circadian rhythms as he/she continuously interacts with the environment. Optimum health can only be achieved when these circadian rhythms are synchronized with life style and life cycle. However, there is little information regarding if, and to what extent elevated blood pressure levels alter and reorganize blood pressure and heart rate circadian rhythmic patterns in the hypertensive adolescent population.

These findings would have nursing implications as they would shed some understanding of circadian variations and the complex, multiple factors modulating blood pressure. This understanding of an individual's early natural history is a prerequisite for primary prevention and intervention with the ultimate goal to be the directing and redirecting of patterns of the human and environmental fields for realization of maximum health potential.

CHAPTER II

REVIEW OF LITERATURE

A literature review provides impetus for this cardiovascular circadian rhythm study. It is not exhaustive but does discuss hallmark studies revolving around the following concepts: (a) Martha Rogers' Science of Unitary Human Beings; (b) cardiovascular circadian rhythmicity in neonates, children, and adolescents; and (c) ambulatory blood pressure monitoring.

Rogers' Science of Unitary Human Beings

Rogers first introduced her general systems deductive nursing theory in 1970. This conceptual system derives descriptive, explanatory, and predictive principles that direct the art and science of nursing practice. It was not until 1977 that hypotheses were derived solely from this theoretical framework (Ference, 1986). Rawnsley (1977) studied the relationship between time perception and the dying process seeking either to verify or refute Roger's helicy principles. Four hypotheses were tested:

1. Older persons perceive time as passing more swiftly than younger persons.

2. Persons who are dying perceive time as passing more swiftly than persons who are not dying.

3. Younger persons who are dying perceive time as

passing more swiftly than older persons who are not dying.

4. There is no relationship between a person's perception of the speed of time passing and his or her estimation of an interval of clock time.

A total of 108 subjects (41 men and 67 women) were categorized into four groups: Group A (Older-Dying) 30 persons between the ages of 55 and 75 with a diagnosis of metastatic cancer; Group B (Older-Not Dying) 30 persons between the ages of 55 and 75 with a non-life-threatening diagnosis; Group C (Younger-Dying) 18 persons between the ages of 17 and 30 with a diagnosis of metastatic cancer; and Group D (Younger-Not Dying) 30 persons between the ages of 17 and 30 with a non-life-threatening diagnosis. Subject awareness of diagnosis was confirmed by asking: (a) the nursing staff if the patient had been informed of his/her diagnosis; and (b) the subject what brought him/her to the hospital. Six research assistants participated in data collection. They administered two instruments to measure subjects' time perceptions. The Time Metaphor Test (Knapp and Garbutt, 1959) studied relationships between time imagery and the achievement motive. The Time Opinion Survey (Kuhlen & Monge, 1968) assessed five factors associated with the perceived rate of passing time (the speed of time passage, future orientation and achievement, feelings of time pressure, ability to delay gratification, and current

life conditions). The author appropriately recognized: (a) the debate concerning the meaning of different clock time estimation methods; and (b) not generalizing the study's findings beyond the sample.

One-way analysis of variance results did not support the first three hypotheses. Pearson Product Moment Correlation determined that there was no relationship between perception of the speed of time passing (felt time) and the estimation of an interval of clock time (cyclic time).

Rawnsley (1977) suggested that the conceptual relationships between the constructs of size, density, boundary, and motion of the human field offered a different perspective of the dying process. She posed thought-provoking questions for future research and is to be commended for initially testing Rogerian Theory. However, a critique of the study revealed: (a) inconsistent and vague operational and conceptual definitions of time; (b) the need for additional refinement in study design and methodology including stratified random rather than purposive sampling; (c) artificiality of the groups as they are not mutually exclusive; and (d) no apparent recognition of such intervening variables as medications, wake/sleep cycle, severity of illness, and the subjects' various developmental stages.

Malinski (1980) employed Rogers' Theory of Accelerating Evolution to assess potential correlations between hyperactivity and short wavelength light perception. It postulates changes to proceed in the direction of higher wave frequency pattern. Organization is characterized by growing diversity. Therefore, the question may be asked, "Have hyperactive children evolved further in the direction of higher light frequency patterns than "normal" children?" If so, would it be manifested with: (a) perception of numbers illuminated in field of short wavelength light; and (b) color preferences among spiral hues associated with long and short wavelength light?

After parental and child consent had been obtained, 104 boys, ages 8 through 12 years, volunteered to participate. A rating scale for hyperactivity was analyzed for reliability, interrater reliability and discriminant ability. Although the scale was found to be reliable and to distinguish between diagnosed and nondiagnosed groups, it provided only one perspective of an already ambiguous or dependent variable. The investigator appropriately sought to control for certain extraneous factors. A diagnosis of dyslexia or brain injury was reason for sample exclusion. Each subject was screened to rule out color blindness.

Although Malinski (1980) was specific in her

operational definition of color perception, only a limited range of responses was available. While the methodology was sufficiently described so as to permit replication, its link with the theoretical framework requires further elucidation. The author recognized that lack of support for the research hypotheses may be primarily attributed to the methodological rather than the theoretical framework. She is to be commended for conducting exploratory research important to the nursing profession.

An experimental pilot study conducted by Gill and Atwood (1981) studied the relationship of epidermal growth factor (EGF) and epidermal wound healing. The Rogerian Principles (1980) of Reciprocy and Helicy provided the theoretical structure. (Reciprocy is currently termed the Principle of Integrality and describes the continuous mutual human field and environmental process.) Operationally, the human field was the keratinocyte adjacent to the wound edge. The environmental field was what was external to the keratinocyte's plasma membrane. The space-time continuum was operationalized as the mitotic cell cycle. In other words, reciprocy was the process and helicy was the background structure of the process.

A primary purpose of the study was to determine if topical application of EGF increased not only the mitotic index but also the rate of differentiation and migration of

keratinocytes over the wound. At prescribed intervals, varying EGF concentrations were applied to a series of small epidermal excision wounds on the back of a young Yorkshire-mix pig. Sodium chloride 0.9% was similarly applied to control wounds. Biopsies were performed on randomly assigned wounds and their controls at specified times.

The hypotheses were supported. As the concentration of EGF was increased, the rate at which the wound was reepithelialized was increased, and the cell number covering the wound was a triple layer rather than a single layer as seen in the controls (Gill & Atwood, 1981).

Floyd (1983) designed two studies investigating sleep-wakefulness patterns in: (a) rotating and nonrotating shift workers; and (b) hospitalized psychiatric patients and psychiatric outpatients. The purpose of the first study was to test the following hypotheses derived from the theorem that shift rotation is the source of environmental disruption. It was speculated that rotating shift workers would report: (a) more total wakefulness time; (b) a higher frequency of sleep-wakefulness cycles; (c) greater variance in total wakefulness time; and (d) greater variance in frequency of sleep-wakefulness cycles than the nonrotating shift workers (Floyd, 1983).

Thirty rotating and 30 nonrotating shift workers were matched according to age and sex. They completed a modified

version of a sleep chart originally developed by Lewis and Masterson in 1957. Since drug use was an extraneous variable, biological psychiatrists rated the effects of all drugs used by the subjects on sleep-wakefulness patterns. (Interrater reliability was from 0.79 to 0.86.)

Although the first two hypotheses concerning increasing complexity were not statistically significant, there were trends in the predicted directions for both hypotheses (Floyd, 1983). Rotating shift workers slept an average of 0.33 hours less than nonrotating shift workers [$F(1,53) = 3.89$ ($p < .10$)]. Similarly, there was a trend toward rotating shift workers reporting a higher frequency of sleep-wakefulness cycles than nonrotating shift workers [$F(1,53) = 3.53$ ($p < .10$)].

The two hypotheses concerning increasing diversity were, however, both statistically significant ($p < .05$). Hartley's test of homogeneity of variance revealed that rotating shift workers had greater variance on total wakefulness time [$F_{MAX}(2,59) = 2.71$] and higher frequency of sleep-wakefulness cycles [$F_{MAX}(2,59) = 2.25$] than did nonrotating shift workers (Floyd, 1983).

Floyd's (1983) matched-pairs design study was conducted to test hypotheses derived from the theorem that hospitalization is the source of environmental disruption. Hospitalized psychiatric patients were

predicted to have more complex and diverse sleep-wakefulness rhythms than psychiatric outpatients. The process of hospitalization was conceptualized as resulting in an encounter between the individual's sleep-wakefulness rhythm and a new environmental rest-activity pattern (Floyd, 1983).

Thirty-five hospitalized subjects were matched with 35 outpatient controls on the variables of psychiatric diagnosis and sex. The covariates were age and drug effects. The covariate scores were obtained from physicians' ratings. The independent variable was hospitalization and the dependent variables were total wakefulness time and frequency of sleep-wakefulness cycles. The validity of the modified Lewis and Masterson (1957) sleep chart was established by comparing nursing records of the hospitalized subjects' sleep with their self-reports.

Hospitalized subjects were awake almost 60 minutes more per 24-hour period than the matched outpatient subjects [$F(1,33) = 4.78$, $p < 0.05$] (Floyd, 1983). Therefore, the hypothesis that hospitalized psychiatric patients will report more total wakefulness time than outpatient controls was supported. However, the remaining three hypotheses were not supported. The hospitalized subjects did not demonstrate greater frequency of sleep-wakefulness cycles, nor report more variance in total wakefulness time or

frequency of sleep-wakefulness cycles than the nonhospitalized subjects. For both studies, Floyd appropriately recognized research limitations which might have contributed to the findings.

Smith (1986) sought to provide empirical support for Rogers' Integrality Principle. The directional hypothesis stated that the perception of restfulness would be lower for subjects who experienced varied harmonious auditory input than for those who experienced quiet ambience. In other words, the individuals in the first environmental setting would be more rested.

Sixty men and 60 women between 18 and 35 years of age participated in this two-group pretest-posttest experimental design study. Borg's 15-item rating scale of perceived exertion (1971) was modified in order to measure perceived restfulness. ("Light" in the Borg instrument was changed to "rested" and the term "tired" replaced "heavy".) Two independent studies testing the modified tool determined it to be a reliable measurement of perceived restfulness. Correlation coefficients were 0.71 and 0.68.

The harmonious auditory input was composed of varying intervals of music or story alternating with varying intervals of silence. The quiet auditory input was the ambient environment of the laboratory maintained at quiet conditions for 150 minutes. The hypothesis that varying

patterns of auditory input were more restful than quiet ambience ($p = .05$) was supported (Smith, 1986).

Cardiovascular Circadian Rhythmicity

Research in the field of human circadian (24-hour) rhythms has a history of approximately 150 years, although it is only during the last 20 years that real progress has been made toward a better understanding of the mechanisms involved. A multioscillator system promotes temporal order within the organism, keeping diverse rhythms in distinct phase relationships with one another as daily changes occur (Aschoff et al., 1967; Aschoff & Wever, 1976; Moore-Ede et al., 1976).

An extensive literature search revealed five studies investigating cardiovascular circadian rhythmicity in neonates, children, and adolescents. This research is summarized below.

Heilbrügge (1960) reported study results investigating the onset of infant heart rate circadian rhythmicity. Ninety-six subjects participated. The findings were:

1. Not until the sixth week were daily periodic heart rate changes observed.

2. The heart rate of infants 6- to 18-weeks-old was lower during nighttime than during the day. The intensity of these daytime peaks and nighttime troughs increased as

the infant became a toddler (age-21 months). The amplitude increase was exclusively produced by a lowering of the heart rate during the night. The nocturnal mean pulse frequency values decreased from 120 beats per minute in the 5- to 8-month-old group to 100 beats per minute in the 11- to 21-month-old-subjects.

3. As the infant aged, the morning rise in pulse frequency reached the mean diurnal value later in the day. This occurred in: (a) 6- to 18-week-old infants between 1:00 a.m. and 3:00 a.m.; (b) 5- to 8-month-old infants between 3:00 a.m. and 5:00 a.m.; and (c) in small children between 5:00 a.m. and 7:00 a.m.

4. Up to 6-months of age, heart rate demonstrated a bimodal daytime rhythmicity. One rhythm peaked in the morning between 7:00 a.m. and 11:00 a.m.; the second rhythm peaked in the afternoon between 3:00 p.m. and 5:00 p.m. From 6- to 12-months-old, a pronounced day/night heart rate rhythmicity was observed.

Halberg et. al. (1984) investigated the circadian systolic and diastolic hyperbaric indices (HBI's) of young people. While in secondary school or college, 117 boys and 147 girls, 14-21 years-old, took their own blood pressures at one hour or longer intervals for varying spans (Halberg et. al., 1984). For each sex, the mean acrometron was determined for systolic/diastolic blood pressure. The mean

acrometron was ascertained from rhythmometric analysis and is the mean of the sum of mesor plus amplitude for each individual. The acrometron values were then employed for the computation of the corresponding HBIs.

Values of 125.0 and 112.3 mm Hg for systolic blood pressure and of 75.1 and 72.3 mm Hg for diastolic blood pressure were found for the acrometron of boys and girls respectively (Halberg et al., 1984). The HBIs were quite skewed. In boys, the HBI for systolic and diastolic blood pressure equalled zero in 64 and 49 of the series respectively. In girls, a zero HBI was demonstrated in 78 of the systolic and 72 of the diastolic blood pressure series.

The HBI did identify a few subjects as outliers. The researchers recommended continued tracking for these individuals so that if warranted, appropriate intervention might be prescribed. Halberg et al. (1984) appropriately identified study limitations including certain analyses and the samples' broad age ranges. It was not mentioned, however, what attempts were made to minimize the effects of extraneous factors, i.e. physical activity, emotions, diet, medications, or wake/sleep patterns. This is an inherent limitation in human chronobiological research. The research did contribute to an increasing cardiovascular circadian rhythm data base which may eventually identify the most

sensitive and accurate chronobiological parameters pertaining to high blood pressure. These may then be utilized to: (a) identify those individuals at greatest risk to develop hypertension, and (b) better understand the complex factors modulating blood pressure.

Florentine school children were asked to participate in two studies assessing systolic/diastolic circadian rhythmicity. Nine-year-old students were taught to take their own blood pressure measurements every two hours for 32 hours beginning at 7:00 a.m. (Scarpelli, Marz, Cornélissen, Romano, Livi, Scarpelli, Halberg & Halberg, 1985). One year later, self-measurements were again obtained. Of the original 424 youngsters, 221 monitored their blood pressure at two hour intervals from 7:00 a.m. to 11:00 p.m. for one or two days.

A medical family history ascertained which children had: (a) no family history of hypertension or diabetes; (b) only a family history of high blood pressure; (c) a history of diabetes only; and (d) a history of both high blood pressure and diabetes. However, the investigators did not discuss: (a) what instrument was employed to obtain this family history; (b) who obtained the diagnosis; (c) how it was confirmed; and (d) family history's operational definition. Limitations recognized by the investigators included: (a) the subjects' maturation from 1983 to 1984;

(b) only 50 percent of the students participating the second year; (c) no nighttime data obtained in 1984; and (d) sparse self-measurement intervals.

Although continued research is warranted, preliminary rhythmometric analysis suggested that children with and without family histories of hypertension and other vascular diseases demonstrated varying fluctuations in mesor, amplitude and acrophase (Scarpelli et al., 1985). Hyperbaric indexes identified that approximately 14 percent of the 1983 sample merited continued blood pressure tracking.

Scarpelli, Romano, Cagnoni, Livi, Scarpelli, Bigioli, Corti, Croppi, DeScalzi, Halberg, Halberg, and Halberg (1985) had determined that 9-year-old students were sufficiently mature to participate in the study. Blood pressure self-measurements were obtained: (a) every two hours from 7:00 a.m. to 11:00 p.m.; and (b) at 1:00 a.m. and 3:00 a.m. Concerning validity and reliability, the authors recognized: (a) the existence of a digit preference when taking one's own blood pressure; (b) lack of precision; and interindividual variability. Not cited as a limitation was the possible circadian rhythm alteration secondary to awakening the children twice during the night for self-blood pressure measurement.

The research did not report: (a) the total number of

children studied nor the number of days they participated; and (b) the actual data. Rather, a summary of the findings recommended that circadian amplitude may represent an individual or group genetic marker of hypertension (Scarpelli et al., 1985).

In 1986, Halberg, Cornelissen, Bingham, Tarquini, Mainardi, Cagnoni, Panero, Scarpelli, Romano, März, Hellbrügge, Shinoda, and Kawabata sought to predict the likelihood that neonates will develop high blood pressure. Within one to two days post-partum, heart rate and systolic/diastolic/mean arterial blood pressures were automatically monitored in 20 neonates at 30-minute intervals for 48 hours.

The authors concluded that neonatal automatic noninvasive blood pressure monitoring had merit as systolic blood pressure linear trend and circadian amplitude in those babies with a family history of hypertension were significantly more prominent than in those without such a family history. Halberg and associates (1986) recognized: (a) the multifactorial origin of hypertension and (b) that linear trend statistical analysis was only a first approximation. However, not addressed were the following: (a) the numerous new external cues introduced to the neonate, i.e. hospital environment and procedures, which may have influenced physiological rhythms; (b) how undetected

cardiovascular and pulmonary anomalies / complications / symptoms, and how subject movement, crying, position, and the startle reflex may have affected blood pressure measurement accuracy and sensitivity; (c) how the naturally occurring neonatal circulatory changes within the first 48 hours affected the findings; and (d) how the hypertensive family history was obtained and its operational definition.

Ambulatory Blood Pressure Monitoring

Recent advances in medical technology have developed fully-automated, portable, noninvasive monitors which can record blood pressure for up to 48 hours. Multiple readings are essential if blood pressure variability over a period of time is to be detected. A single casual measurement cannot accurately reflect: (a) diurnal blood pressure variation; (b) the severity and duration of elevated blood pressure levels; or (c) response to medical regimens (Drayer, 1985; Frohlich, 1986; Wallace, 1979). Further impetus for the employment of automatic blood pressure monitoring is warranted in that several casual blood pressures obtained on separate occasions are not superior to a single measurement as their values tend to regress toward the mean (Pickering et al, 1985).

Harshfield et al. (1979) correlated the Del Mar Pressurometer II Ambulatory ECG and Blood Pressure Recording

System with indirect and direct arterial measurements. To obtain the indirect measurement comparisons, 15 subjects wore the Pressurometer to which a mercury sphygmomanometer had been connected. Ten concurrent readings were obtained in each of three positions (sitting, standing, and reclining). Data were similarly collected in five subject while they walked.

For direct arterial comparisons, five males already scheduled for arteriograms were fitted with the Pressurometer. Thirty measurements were taken concurrently with intra-arterial readings. Pearson Product Moment Correlation for Related Samples (Pearson r or r_p) and *t*-tests were employed to ascertain the instrument's reliability and validity respectively.

Comparing the Pressurometer readings with the mercury sphygmomanometer measurements indicated that:

1. During rest, the r_p for all subjects equaled 0.99 for systolic blood pressure and 0.94 for diastolic blood pressure ($p = .001$). Individual correlations ranged from $r_p=0.64$ to $r_p=0.97$ for systolic blood pressure and $r_p=.50$ to $r_p=0.92$ for diastolic blood pressure ($p = .01$).

2. During walking, the r_p equaled 0.95 and 0.86 for systolic and diastolic blood pressure respectively ($p = .01$). When comparing direct and indirect measurements, the r_p equaled 0.98 for both systolic and diastolic blood

pressures (p = .001).

4. For all conditions, t-tests demonstrated no significant differences between the two blood pressure measurements.

Horan et al. (1981), investigated 24-hour ambulatory blood pressure patterns in borderline (labile) hypertensive patients. Sixty-three subjects (51 men and 11 women) were evenly stratified according to blood pressure measurements taken on at least three separate occasions. Twenty-one subjects with recordings above and below 140/90 mm Hg and not taking medication were assigned to the labile hypertensive group. If the blood pressure screening values were consistently above or below 140/90 mm Hg, individuals were assigned to the fixed hypertensive and normotensive groups respectively. Demographic characteristics revealed that: (a) the borderline hypertensive individuals were younger than either the fixed hypertensive or normotensive groups; and (b) caucasian males dominated the normotensive and borderline hypertensive groups whereas black males composed the majority of the fixed hypertensive group. Heights and weights were not presented nor was it mentioned if antihypertensive therapy was temporarily discontinued prior to data collection.

The Del Mar Avionics Pressurometer II ambulatory blood pressure unit automatically recorded heart rate and blood

pressure measurements every 7.5 to 15 minutes over 24 hours. The findings give impetus to the central role 24-hour ambulatory blood pressure monitoring may play in accurately assessing blood pressure variability.

1. While the mean 24-hour systolic and diastolic blood pressures were significantly different ($p < .005$) among the three groups, the standard deviations were not.

2. The percentages of elevated blood pressures demonstrated broad variability in those individuals classified with borderline hypertension. The percentages ranged from 7.9 to 81.3%. The normotensive group had the smallest while the fixed hypertensive subjects demonstrated the largest number of elevated blood pressures.

A study conducted by Pickering et al. (1982), also studied individuals classified as normotensive, borderline hypertensive, and hypertensive. The purpose was to ascertain any blood pressure differences among the three groups in four settings: (a) physician's office; (b) work; (c) home; and (d) sleeping. Response to exercise was monitored every 90 seconds via sphygmomanometer throughout a standard Bruce Treadmill test.

Each subject was fitted with the Del Mar Avionics Pressurometer II ambulatory blood pressure recorder which had been programmed to record readings for 24 hours at 15 minute intervals. When the unit was connected to and

disconnected from each subject, a minimum of five blood pressure measurements were obtained. These readings had to be within 5 mm Hg of simultaneous readings obtained with a stethoscope and mercury column for the recording to be considered acceptable (Pickering et al., 1982). The subjects were instructed to record activities in a diary with each blood pressure cuff inflation. All recordings were edited according to specific criteria with approximately 15 percent of the readings rejected as artifact.

An analysis of variance revealed that for all three groups, there was a suggested trend for blood pressure measurements obtained in the work setting to be higher than those taken in the physician's office. However, differences between clinic and home readings were significant for systolic ($p < .01$) and diastolic ($p < .05$) blood pressures. A Newman-Kuels post hoc test specifically identified that both the borderline hypertensive and hypertensive subjects demonstrated consistently higher pressures in the office setting than at home ($p = .05$ and .01, respectively). Conversely, normotensive individuals showed no significant difference in blood pressure measurements between these two settings. All three groups revealed similar blood pressure responses to sleep and exercise.

When assessing blood pressure variability, no consistent differences between the three groups for either systolic or diastolic blood pressure were observed. Also, the borderline hypertensive subjects did not demonstrate increased blood pressure lability. The authors conclude that especially in patients with borderline hypertension, office readings may misrepresent one's overall blood pressure level. Twenty-four ambulatory blood pressure monitoring would therefore be most illuminating in this population.

Twenty-nine men diagnosed with benign essential hypertension were matched for age and sex with 29 normotensive individuals (Drayer et al., 1985). It was retrospectively determined that the two groups did not significantly differ with respect to height, weight, or degree of obesity. The authors attempted to control the impact of certain external stimuli by: (a) discontinuing antihypertensive medications two weeks prior to data collection; and (b) encouraging participants to maintain as near a normal working day as possible.

The men wore the Del Mar Avionics Pressurometer III ambulatory blood pressure monitor for one 24-hour period. The unit was programmed to obtain heart rate and systolic/diastolic blood pressures at 7.5-minute intervals. Data were analyzed to assess: (a) blood pressure

variability; (b) differences in the prevalence of abnormal blood pressures between the two groups; and (c) possible differences in blood pressure circadian patterns. (Note: Rhythmometric analysis was not employed. Rather, the averages of systolic and diastolic blood pressures were obtained during the 12 consecutive 2-hour periods.)

The findings were:

1. Systolic and diastolic blood pressure variability was defined as the standard deviation of all blood pressures measured during the 24-hour monitoring period. For normotensive and hypertensive men, it was $15\pm4/11\pm3$ mm Hg and $14\pm5/12\pm3$ mm Hg respectively. However, for both groups, systolic blood pressure demonstrated significantly greater variability ($p < .05$) than did diastolic blood pressure.

2. Hypertensive subjects demonstrated greater percentages of abnormal systolic and diastolic blood pressures (46% and 56% respectively) than the normotensive individuals (12% and 14% respectively). However, both the hypertensive and normotensive groups revealed a marked range in the incidence of abnormal pressures.

3. The hypertensive group's blood pressure circadian rhythm pattern paralleled that of their normotensive counterparts but at a significantly higher level.

Garrett et al. (1985) studied blood pressure response to exercise in adolescents with exercise-induced hyperten-

sion. It was anticipated that 24-hour ambulatory blood pressure monitoring might shed additional information in these individuals' responses to "routine" physical activity.

Ten black hypertensive and ten black normotensive adolescents matched for age underwent a standard bicycle ergometer test. During this procedure, all hypertensive subjects developed a systolic blood pressure greater than 240 mm Hg as determined by a standard mercury sphygmomanometer and blood pressure cuff. After exercise, there was also a delayed return to baseline blood pressure values in this sample.

The Del Mar Avionics Pressurometer III then monitored blood pressure for one 24-hour period at 7.5 minute intervals. It revealed that in the hypertensive group:

1. There was no significant difference in mean blood pressure between morning and evening values.

2. There was no reduction in mean blood pressure or pulse pressure during the evening hours.

3. Variability demonstrated no significant change between daytime and nighttime.

4. Normal circadian fluctuations were not observed. Rather, the blood pressure pattern was linear (Garrett et al., 1985). The normotensive subjects, however, demonstrated a significantly lower variability, a reduction in pulse pressure during sleep, and normal circadian

variation when compared with their hypertensive counterparts.

A Case/control study was conducted to ascertain blood pressure differences in 252 adolescents with (N = 126) and without (N = 126) a documented family history of hypertension (Brenner, Dischinger, Wilson, Gardner, Berman, & Ferencz, in press). A hypertensive family history was considered positive if at least one parent had a diastolic blood pressure $\geq$ 95 mm Hg and/or was receiving antihypertensive medication. Adolescents who had two normotensive parents (a diastolic blood pressure $\leq$ 80 mm Hg in one and $\leq$ 85 mm Hg in the other) were considered controls. Not discussed was: (a) why systolic blood pressure was not considered in the operational definition; and (b) the number of measurements obtained before considering a parent hypertensive.

Individuals between 13 and 19 years of age were selected from a representative sample of Maryland homes which had previously participated in a statewide blood pressure screening program. Because there was a greater number of young people without a family history of hypertension, an equal random sample of control subjects (N = 126) was obtained. Observer bias was minimized as the lists of the two groups were merged so that all personnel assisting with data collection were blind to participant

status.

For one 24-hour monitoring period, the Del Mar Avionics Pressurometer III device monitored blood pressure and heart rate measurements at 7.5-minute intervals. Prior to data collection and at its conclusion, instrument validity checks were conducted. Default settings automatically edited certain measurements while manual editing was facilitated by specific criteria and a detailed activity diary. Readings were then divided into time spent in school, awake, and asleep.

Although not included, subjects' heights and weights and a stepwise regression analysis would have enhanced data interpretation. Standard *t*-tests revealed:

1. Significant differences in heart rate and systolic/diastolic blood pressures between subjects who wore the unit to school (N = 61) and those who did not (N = 174). When the Case/control status was an additional determinant, students with a hypertensive family history had a significantly higher mean systolic blood pressure than their Case counterparts who were monitored at home. Control subjects, however, demonstrated no such difference.

2. Significant differences in awake mean hourly systolic and diastolic blood pressures between the two groups (p = .02 and .03, respectively). The percent of elevated awake systolic blood pressure ($\geq$140 mm Hg) for

those with a positive family history was twice that observed in those without such a history. The authors conclude that

> since the long-term sequelae of hypertensive disease is likely the result of not only the peak level of blood pressure encountered but also the percentage of time spent at that elevated level, the ability to determine blood pressures over time allows better definition of the normal and abnormal range (p.9).

The Gould et al. (1985) study was unique for it sought to compare measurements obtained by the Del Mar Avionics Pressurometer III device with simultaneous intra-arterial blood pressure readings taken at home, at the hospital, and during exercise. Simultaneous comparisons were also made with measurements obtained by mercury sphygmomanometer.

During clinical trials, 12 men and 10 women were monitored intra-arterially and wore the Del Mar Avionics Pressurometer III for one day during waking hours. Research methodology was sufficiently described so as to permit replication. Before leaving the clinical environment, each subject was instructed how to: (a) use the Pressurometer at home; and (b) record in the activity diary.

Data from two subjects were rejected according to edit criteria for absolute and suspected artifact (Kennedy et al, 1979). Pressures recorded by the Avionics Pressurometer at home and at hospital were compared with each other and with simultaneous intra-arterial one-minute average blood pressures (Gould et al., 1985). The mean difference with

standard deviation (SD) for intra-arterial versus Avionics blood pressure was: (a) 2 (SD 8.6) / -14 (SD 10.3) mm Hg at home; and (b) -3 (SD 15.4) / -11 (SD 12.3) mm Hg at the hospital. At the conclusion of a prescribed bicycle ergometer exercise, similar comparisons yielded -7 (SD 16) / 0 (SD 15.6) mm Hg.

Avionics and intra-arterial comparisons of blood pressures measured in both home and clinical settings demonstrated small mean systolic but large mean diastolic differences. Mean hourly daytime Avionics pressures were compared with mean hourly daytime intra-arterial monitoring by employing paired Student's t-tests. The trend plot revealed that the systolic and diastolic pressures recorded by the Avionics Pressurometer were significantly higher than the intra-arterial pressures. A scatterplot and frequency histogram also visualized that clinic systolic and diastolic pressures overestimated the intra-arterial blood pressures. The observation was made with the knowledge of wide individual variation.

The authors concluded that because of: (a) wide individual variation during bicycle exercise; and (b) increasing systolic discrepancy and continued wide individual fluctuation post-exercise, the Avionics Pressurometer had limited use during physical exertion.

The accuracy of the Dinamap oscillometric blood

pressure unit was evaluated in a study conducted by Park and Menard (1987). Twenty-nine pediatric patients with radial arterial lines provided the opportunity to compare indirect oscillometric technique with direct arterial measurement. At the time of data collection, the mechanically ventilated subjects had either been sedated or had spontaneous respirations completely suppressed with medication. A two-channel ink-writing recorder (Gould Recorder 2200S) had been connected to: (a) the pressure amplifier to record arterial pressure; and (b) the Dinamap monitor to record the beginning and end of blood pressure cuff inflation.

In 20 of the 29 infants/children, auscultatory comparisons with the Dinamap device were also made. The same Dinamap cuff and a mercury sphygmomanometer were utilized. One observer marked the beginning and end of cuff deflation while another observer recorded the auscultatory pressure readings for later comparison with the strip chart values.

The linear regression equation with correlation coefficient between direct arterial (x) and the Dinamap (y) measurements was: (a) $y = 1.05x - 5.36$ ($r = .97$) for diastolic blood pressure; (b) $y = 1.10x - 4.65$ ($r = .903$) for diastolic blood pressure; and (c) $y = 1.06x - 4.21$ ($r=.917$) for mean pressures. The linear regression equation

with correlation coefficient for auscultatory/Dinamap comparisons was y = 1.60x - 68.23 ($\underline{r}$ = .872) and y = 1.38x- 16.47 ($\underline{r}$ = .874) for systolic and diastolic blood pressures respectively. Mean error with standard deviation for the Dinamap method (-0.24 $\pm$ 3.26 for systolic; 1.28 $\pm$ 4.74 for diastolic; and 0.10 $\pm$ 4.56 mm Hg for mean pressures) was smaller than that obtained by auscultatory technique (-1.65 $\pm$ 6.68 for systolic and 8.79 $\pm$ 5.97 for diastolic pressures). Discussion of the study's methodological strengths and limitations was quite comprehensive.

Two studies (Dembroski & MacDougall, 1985; Pagny, Chatellier, Devries, Janod, Corvol, & Menard, 1987) evaluated the SpaceLabs Model 5200 Monitor - the immediate predecessor of the SpaceLabs 90202 Model utilized in this dissertation research.

Dembroski and MacDougall (1985) compared those blood pressure measurements generated by the SpaceLabs 5200 Monitor with those obtained simultaneously by mercury sphygmomanometer. Twenty subjects wore the unit for varying lengths of time. A technician trained in clinical blood pressure recording obtained standard auscultatory systolic blood pressure and Phase V diastolic blood pressure measurements on the subject's right arm while a second technician manually triggered the device and recorded pressure readings from the unit's liquid crystal display.

However, it was not specified: (a) when the monitor was activated; and (b) if any interarm blood pressure differences were determined.

The findings were as follows.

1. The mean systolic and diastolic blood pressures compared within ± 3 mm Hg of each other in 16 and 15 subjects respectively.

2. Since a subject's average data may disguise the presence of significant random error measurement, the data from all 20 subjects were pooled to yield a sample of 177 paired observations for both systolic and diastolic blood pressure. Frequency analysis of the size of the differences for each pair was employed. It revealed that 91% of systolic blood pressure readings were within ± 7mm Hg of each other while 90% of the diastolic blood pressure measurements reflected a similar variation.

3. The correlation between auscultatory and oscillometric techniques employing averaged data for each subject was r = .98 for systolic blood pressure and r = .94 for diastolic blood pressure.

4. While the subjects' overall mean blood pressures were similar, individual measurement comparisons indicated the unit readings to demonstrate greater variability. Paired t-tests for these measurement standard deviations yielded significant differences for systolic (t = 3.61, df =

19, $p < .01$) and diastolic ($t = 2.73$, $df = 19$, $p < .02$) blood pressures. The authors recognized that the possibility of nonsystematic monitor error and technician measurement bias because of previous knowledge may have contributed to this variation.

5. The relationship of both measurement techniques was highly linear and approximately homoscedastic. However, the regression slopes deviated from unity.

Dembroski and MacDougall (1985) concluded by comparing their findings with other research and by suggesting topics for future research.

Blood pressure recordings were simultaneously recorded by the SpaceLabs 5200 and Remler M2000 ambulatory monitoring devices (Pagny et al., 1987). The SpaceLabs unit is an oscillometric monitor as compared to the Remler M2000 which relies solely on Korotkoff sounds. Twenty-four individuals participated. The authors classified 11 subjects as hypertensive if a single casual auscultatory diastolic blood pressure measurement was greater than 90 mm Hg. The rationale for this arbitrary categorization was not specified. However, the methodology was adequately described to permit replication.

Statistical analyses included the paired t-test, the Wilcoxon, and regression coefficients. Analysis of daily averages of all recorded ambulatory pressures demonstrated a

strong correlation between the two methods for systolic (r = .95, N = 24, p < .001) and diastolic (r = .93, N = 24, p < .001) blood pressures. The range of individual variations of systolic blood pressure was -9.3 to +17.2 mm Hg (Pagny et al., 1987). Diastolic blood pressure data were less consistent. When paired Remler and SpaceLabs measurements were analyzed, there was a strong correlation between the two devices for both systolic and diastolic blood pressures (r = .85, N = 324, p < .001).

The authors appropriately recognized that the different methods of measurement employed by the two ambulatory blood pressure monitors may have accounted for some of the variability. It was determined that interarm blood pressures were not a factor. Apparently Pagny et al. did not consider the definition of hypertension nor the method by which subjects were assigned to either a normotensive or hypertensive category to be limitations.

Summary

The literature review revolved around three concepts: (a) Martha Rogers' Science of Unitary Human Beings; (b) cardiovascular circadian rhythmicity in neonates, children, and adolescents; and (c) ambulatory blood pressure monitoring. Six studies conducted from 1977 to 1986 employed Rogers' deductive nursing theory in diverse settings. The strengths, limitations, and contributions of

pioneering and recent cardiovascular circadian rhythm research (1960 to 1986) were discussed in five studies. Also presented were ten hallmark studies investigating ambulatory blood pressure monitoring from 1979 to 1987; eight utilized ambulatory blood pressure monitors other than the SpaceLabs unit. The SpaceLabs 5900 Model (predecessor to the SpaceLabs 90202) was employed in the remaining two studies. All articles were selected to: (a) illustrate what has been done in the various fields; and (b) provide a research base for the methodology employed in this dissertation research.

CHAPTER III

PROCEDURE FOR COLLECTION AND TREATMENT OF DATA

This study is classified as quantitative-descriptive, hypothesis-testing field research (Kerlinger, 1973; Polit & Hungler, 1983). Cardiovascular relationships are predicted in adolescents as they go about their daily routines. The investigation and data collection are designed to determine if there are significant differences in cardiovascular circadian rhythmicity between these normotensive and hypertensive individuals.

Despite the study's ex post facto character, the investigator sought to strengthen the study design by promoting some degree of sample representativeness. Normotensive adolescents were stratified according to age, sex, and ethnicity. Students from certain strata were randomly selected so as to match with their hypertensive counterparts on these three variables. Field studies permit control of some aspects of the research (Meyers & Grossen, 1978). The investigator asked the students to maintain as near a normal day-active schedule as possible. Data collection was rescheduled if illness, travel outside the local time zone, or a change in wake-sleep patterns

occurred.

Setting

The study was conducted in two settings:

1. The nurse's office at a large, metropolitan health magnet high school with an approximate enrollment of 600 students.

2. A pediatric cardiology department's examining and computer rooms located in a large southwestern metropolitan children's hospital.

Data was analyzed at Dr. Halberg's Chronobiology Laboratories at the University of Minnesota (Minneapolis).

Population and Sample

The population consisted of approximately 600 adolescents enrolled in a health magnet high school (see Figure 2, p. 56). Four hundred of these students obtained parental consent to participate in a blood pressure screening program conducted and coordinated by the investigator. She trained four students to assist in the screening efforts by employing strategies contained in the Program on the Epidemiology of Blood Pressure in Childhood, Youth and Early Adulthood Training Manual (Labarthe, 1985). Students identified as having high blood pressure levels (greater than the age-specific 90th percentile values of blood pressure for sex) and normotensive adolescents with a family history of hypertension were screened on two

additional separate occasions. Twenty-seven students were determined to have high blood pressure. Twenty met the following delimitations:

1. day-active people.
2. 13 to 19 years old (inclusive).
3. enrolled in a metropolitan health magnet high school.
4. able to read and comprehend English.
5. if hypertensive, primary type hypertension only.
6. dysrhythmia-free.
7. not pregnant or taking birth control pills.
8. if normotensive, no family history of hypertension.
9. no history of diabetes or other hormonal problems, renal disease, or cardiac disease (including aortic incompetence and coarctation of the aorta). Thirteen hypertensive individuals agreed to participate in the study.

Because of the possible confounding effects of blood pressure medication, other health problems, etc., each hypertensive student was individually assessed for sample inclusion by the investigator and a pediatric cardiologist nationally recognized for his expertise in the area of adolescent hypertension. A stratified random normotensive group was matched with ten hypertensive students for age, sex, and ethnicity.

		ANGLO	BLACK	HISPANIC	ASIAN	OTHER	TOTAL
Grade 9	M	14	14	6	3	1	38
	F	15	87	15	3	0	120
Grade 10	M	7	32	12	0	1	52
	F	15	88	8	0	3	114
Grade 11	M	4	24	9	1	0	38
	F	10	81	11	2	0	104
Grade 12	M	5	22	7	0	3	37
	F	16	64	11	0	4	95
TOTALS:		86	412	79	9	12	598

Figure 2. Number of full time health magnet high school students by grade, sex, and ethnicity.

Protection of Human Subjects

Permission to conduct the study was requested from the University and had already been received from the participating agency (see Appendix A).

The potential risks to the subjects involved in this research were:

1. improper release of data.
2. the possibility of public embarrassment.
3. possible arm discomfort during blood pressure cuff inflation and deflation.
4. possible slight sleep disruption secondary to the unit's noise during cuff inflation.
5. possible blood pressure unit malfunction.

To minimize these risks, the following steps were taken:

1. All files and back-up files were kept at the investigator's home. Subject anonymity was secured by recording all data under a coded number. Any information obtained in connection with this study which could be identified with the subject remained confidential and was disclosed only with parental/guardian and subject permissions.

2. To promote privacy during the thigh blood pressure measurement: (a) it was taken in an examining room with the door closed; and (b) the subject was asked to wear loose fitting shorts.

3. The subject's arm was held straight at his/her side during cuff inflation and deflation. If necessary, the investigator reprogrammed cuff inflation frequency to promote comfort.

4. For the time period from 12:00 midnight to 6:00 AM, the unit was programmed to: (a) inflate every 20 minutes; and (b) had no audible tones immediately before and after the blood pressure measurement.

5. The subject was provided with written information which included a Problem Solving Checklist and instructions on how to remove the blood pressure unit should either the parent/guardian or subject feel it necessary to do so (see Appendix B). The investigator was constantly available via

a beeper should questions or problems have arisen.

The investigator asked adolescents meeting the previously mentioned delimitations to attend a class (as outlined in Appendix C). The purposes of this class were to: (a) present an overview of this study; and (b) obtain a list of those interested in participating. The Parental Consent Form (see Appendix E) was then mailed to all prospective participants and their parents/guardians. The investigator called those not responding to this initial request. Students still desiring to participate were mailed another consent form. The signed form was returned in an enclosed stamped, addressed envelope.

The investigator then called these subjects to schedule an appointment time. A letter (see Appendix D) containing information and directions to Children's Medical Center was then mailed.

Since the research posed minimal risk and a majority of the students were younger than the age of legal consent, parental consent was obtained from one parent or guardian (Human Subject Program Guidelines, 1983). Both the subject and parent/guardian signed the consent form. The "Letter Requesting Parental Consent" (see Appendix E) states, "If you [Parent/Guardian] or your son/daughter decide to withdraw after signing, it is all right to do so." The investigator determined the subjects to be mentally

competent during a: (a) previous blood pressure screening program; and (b) class lecture and discussion presenting an overview of this study.

The participants and their parents/guardians were mailed: (a) a report of their individual data; (b) an abstract of the study's overall findings; (c) a summary of the student evaluations; and (d) a $10 to $30 check made payable to the student. (Amount was contingent upon how long the blood pressure unit was worn.) When the student returned the monitor, the investigator downloaded the data into an IBM-PC compatible Zenith Z-183 PC. If blood pressure or heart rate measurements posed immediate concern, the student and parent/guardian were informed at that time. If they did not have a personal physician, a pediatric cardiologist was available for referral.

Instruments

SpaceLabs 90202 Ambulatory Blood Pressure Monitor

The advent of ambulatory blood pressure monitoring may facilitate the diagnosis of hypertension and the understanding of the complex factors modulating blood pressure. Recent statistics indicate that without such monitoring, 20 to 35 percent of all hypertensive patients are misdiagnosed (G. Pelikan, personal communication, September, 1987). A patient could be erroneously diagnosed

as either being hypertensive or as having normal blood pressure levels. By replacing a single reading with multiple readings over a 24- or 48-hour period, ambulatory blood pressure monitors make it easier to discriminate between occasional abnormal events and those that form a pattern indicative of hypertension (Pelikan, personal communication, September, 1987).

The SpaceLabs 90202 Ambulatory Blood Pressure Monitor employs oscillometric techniques to measure heart rate and systolic, diastolic, and mean arterial pressures. It has been on the market since November 1986 and meets both the Food and Drug Administration's (FDA) and the Association for the Advancement of Medical Instrumentation's (AAMI) accuracy criteria. Numerous studies are being conducted nationwide with preliminary yet encouraging findings.

Reliability

The reliability of the SpaceLabs 90202 Monitor was concurrently assessed during data collection. When the students were being connected to and disconnected from the unit, calibration and auscultatory measurement comparisons were made (as delineated in Appendix F). The mercury sphygmomanometer, against which the monitor was compared, was tested for accuracy by Biomedical Instrumentation at Children's Medical Center. If the SpaceLabs device did not descend in the programmed 4 mm Hg bleed steps nor visually

compare within 3 mm Hg of the mercury sphygmomanometer, the unit was not be used. Auscultatory and oscillometric techniques were required to compare within 6 mm Hg of each other for both systolic and diastolic blood pressures. The Wilcoxon matched pairs-signed ranks test analyzed differences between heart rate and blood pressure measurements when the SpaceLabs 90202 Monitor was connected to and disconnected from each subject (see Table 3).

Table 3

The Wilcoxon Matched Pairs-Signed Ranks Test Comparing SpaceLabs and Investigator Measurements

SYSTOLIC BLOOD PRESSURE -- SpaceLabs vs. Auscultatory

Cases	z	Critical p Value	Observed p Value	Conclusion
59	-1.01	.3127	.3124	NS

DIASTOLIC BLOOD PRESSURE -- SpaceLabs vs. Auscultatory

Cases	z	Critical p Value	Observed p Value	Conclusion
59	-1.96	.0500	.0504	NS

HEART RATE -- SpaceLabs vs. Auscultatory

Cases	z	Critical p Value	Observed p Value	Conclusion
55	-2.40	.0164	.0164	S

Note. p values are two-tailed. The actual table gave one-tailed probabilities under the null hypothesis of z. To obtain the above two-tailed p critical values, the actual table value was multiplied by two. Level of significance is 0.05. NS = No significant difference; S = significant difference.

Because the heart rate critical and observed p values were equal, the null hypothesis was not supported. In other words, there was a small yet significant difference between

the heart measurements obtained by the blood pressure units and those palpated by the investigator. The discrepancy is attributed to: (a) investigator and/or unit measurement error; (b) comparing heart rate obtained via oscillometric technique with that palpated for thirty seconds then multiplied by two; and (c) the time lapse of one to two minutes between unit and palpation measurements.

Validation Study

Observational, descriptive research assessed the similarities/differences between various blood pressure monitoring devices so as to establish the SpaceLabs 90202 Monitor's validity in the pediatric/adolescent population (Polit & Hungler, 1983). Two physicians, a research nurse, and the investigator designed a validation study for this purpose. It was conducted at a large metropolitan children's hospital in three clinical settings: (a) an intensive care unit; (b) a cardiac catheterization laboratory; and (c) a cardiology clinic. These three areas were chosen to: (a) facilitate sample procurement; (b) assess the SpaceLabs unit in a variety of settings; (c) assess the monitor pre- and post-exercise and at rest; and (d) have a sample in which an arterial line would already be available so as to be able to compare indirect with direct blood pressure measurements.

Intensive Care Unit -- Setting, Sample, and Protocol. The

23-bed Children's Intensive Care Unit admits individuals up to 18 years of age (inclusive). Six of these beds compose a Stepdown Unit and three rooms are for isolation cases. The staff treats everything but trauma with a 1:1 to 1:2 nurse:patient ratio. The occupancy rate is 100% a majority of the time.

Newly developed instruments can be effectively pretested with a purposive sample of divergent people (Polit & Hungler, 1983). Criteria for subject inclusion were: (a) between the ages of one and 18 years (inclusive); (b) an intra-arterial line already in place; (c) not having greater than five premature contractions per minute and/or not in atrial fibrillation; (d) no aortic incompetence; (e) no subclavian flap repair; (f) hemodynamically stable; (g) not obese; and (h) no intravenous line in the antecubital fossa, arm deformity, cast, or edema which would interfere with accurate blood pressure measurement. Since the primary purpose was to establish the validity and reliability of the SpaceLabs 90202 Monitor in the pediatric/adolescent population, neither external stimuli nor the effects of anesthesia and/or other medications were reasons for sample exclusion.

Four boys and two girls met the previously mentioned inclusion criteria. Their ages ranged from 1.7 to 6.2 years inclusive (mean = 3.5 years; standard deviation = 1.4

years). All were unconscious at the time of data collection because of their illness/surgery and medications. The subject was in a supine position. The arm in which there was either a radial or brachial arterial line was restrained. Arm circumference was measured with a nonstretchable tape and cuff size was determined by American Heart Association (1980) guidelines. The SpaceLabs and Dinamap devices were separately positioned on the arm not containing the radial or brachial arterial line.

The research nurse obtained all blood pressure measurements while the investigator or pediatric cardiologist coordinated the arterial pressure tracings. The SpaceLabs unit was activated first. When the research nurse auscultated the first Korotkoff sound, she signaled the investigator or physician to begin the arterial pressure tracing recorder. Twelve arterial beat tracings were obtained and averaged; this mean value determined the arterial systolic/diastolic blood pressure measurements for the particular run. The sequence was repeated three times at one to two minute intervals.

Tubing from a mercury sphygmomanometer was connected to the Dinamap tubing via a three-way stopcock to permit simultaneous auscultation of the brachial artery. The research nurse or the investigator activated the Dinamap device. When the research nurse auscultated the first

Korotkoff sound, she signaled the investigator to begin the arterial pressure tracing recorder. Twelve arterial beat tracings were obtained and employed as previously described. This sequence was also repeated three times at one to two minute intervals.

Cardiac Catheterization Lab -- Setting, Sample and Protocol. Approximately ten pediatric/adolescent patients undergo a cardiac catheterization weekly. The lab utilizes a Hewlett-Packard device to measure intra-arterial pressure and the Dinamap #1846 Model for indirect blood pressure monitoring. Heart rate is continuously monitored by the E for M Model #VR12 Simultrace Recorder (Honeywell Division of Electronics for Medicine).

Sample delimitations included utilizing the femoral approach for the catheterization in addition to those previously mentioned for the pediatric/adolescent intensive care unit sample. Three boys and five girls ranging from 3.1 to 10.3 years inclusive (mean = 6.4 years; standard deviation = 2.6 years) underwent a cardiac catheterization. He/she was supine on the catheterization lab table with both arms restrained. Arm circumference was measured with a nonstretchable tape and blood pressure cuff size determined by American Heart Association (1980) guidelines. The SpaceLabs and Dinamap devices were positioned on the right and left arms respectively. Aneroid

sphygmomanometer tubing was connected to the Dinamap tubing via a three-way stopcock. This permitted simultaneous auscultation of the left brachial artery. A catheter inserted into the femoral artery provided the arterial pressure tracing.

At the point of SpaceLabs blood pressure cuff inflation, the research nurse activated the Dinamap device. When she auscultated the first Korotkoff sound, the technician was asked to begin the arterial pressure tracing. The recording was stopped after the fifth Korotkoff sound was heard. Four readings were obtained according to this protocol; two readings one to three minutes apart post-catheter insertion and another two readings one to three minutes apart at a time convenient for the cardiologist.

Cardiology Clinic -- Setting, Sample and Protocol. The hospital's cardiology clinic provided the setting. Children/adolescents greater than or equal to four years of age and determined by their pediatric cardiologist to be able to uneventfully climb 60 stairs were asked to participate. The 11 males and 10 females ranged from 4.3 to 21.9 years inclusive (mean = 11.8 years; standard deviation = 3.9 years).

Blood pressure cuff size was determined from arm circumference as previously described. SpaceLabs and

auscultatory measurements were obtained over the right brachial artery. A t-tube adaptor connected to a mercury sphygmomanometer permitted simultaneous readings. With the subject in a sitting position, two pre-exercise and two post-exercise measurements were taken at one to three minute intervals. The nurse researcher supervised the exercise which required the subject to climb up 60 stairs.

Data Analyses. Although the research design and methodology sought to minimize observer bias and measurement error, it was impossible to determine any nonsystematic error(s) generated by the blood pressure monitoring devices. All data were independently reviewed by the research nurse and a pediatric cardiologist for absolute or suspected artifact. Criteria for these categories were sample specific:

Type 1: Absolute Artifact
- a. A diastolic blood pressure less than 40 or greater than 140 mm Hg.
- b. A systolic blood pressure less than 50 or greater than 246 mm Hg.
- c. A pulse pressure less than 10 mm Hg.
- d. A recorded diastolic pressure that registered higher than the systolic pressure.
- e. A sudden increase (more than 40 mm Hg systolic or 20 mm Hg diastolic) in blood pressure concomitant with exposure to an environmental source of artifact.

Type II. Suspected Artifact
- a. Blood pressure measurements deemed possible but unlikely because they deviated from the individual's trend pattern of blood pressure measurements and occurred immediately before or after a Type I artifactual measurement.
- b. Blood pressure measurements deemed possible, but

the recorded diastolic pressure was greater than the preceding and subsequent systolic pressure measurements.

c. Blood pressure measurements deemed possible, but an abrupt increase in pressure (more than 40 mm Hg systolic or 20 mm Hg diastolic) was not accompanied by an increase in heart rate of at least one beat per minute (D.E. Fixler, personal communication, September, 1987; Kennedy, Padgett, & Horan, 1979).

Scatterplots, frequency histograms, and the paired *t*-test for dependent samples were employed for data analysis (Zezulka, Sloan, & Beevers, 1985). All data measurements, irrespective of clinical setting, were paired as follows: (a) auscultation versus SpaceLabs for systolic blood pressure; (b) auscultation versus SpaceLabs for diastolic blood pressure; (c) arterial versus Dinamap for systolic blood pressure; (d) arterial versus Dinamap for diastolic blood pressure; (e) arterial versus SpaceLabs for systolic blood pressure; and (f) arterial versus SpaceLabs for diastolic blood pressure.

Findings. Specific measures of central tendency and variability are displayed in Table 4. The mean auscultatory systolic/diastolic blood pressure measurements (110.5 and 67.3 respectively) were lower than those obtained by the SpaceLabs oscillometric device (115.0 and 68.3). Direct arterial mean systolic blood pressures, however, were higher (104.9 and 103.9) than those indirectly monitored by the

Table 4

Comparison of Blood Pressure Obtained by Auscultation, Direct Arterial Measurement, and the SpaceLabs and Dinamap Devices

	Mean	S.D.	S.E.
SYSTOLIC BLOOD PRESSURE (mm Hg)			
Auscultation	110.5	23.9	2.1
SpaceLabs	115.0	21.3	1.9
Arterial	103.9	24.8	3.6
Dinamap	90.7	14.9	2.2
Arterial	104.9	23.8	3.5
SpaceLabs	96.5	13.3	1.9
DIASTOLIC BLOOD PRESSURE (mm Hg)			
Auscultation	67.3	13.7	1.2
SpaceLabs	68.4	13.3	1.1
Arterial	53.2	10.3	1.5
Dinamap	55.6	11.1	1.6
Arterial	53.7	10.0	1.5
SpaceLabs	57.6	11.2	1.6

Note. S.D. = Standard deviation; S.E. = Standard error.

SpaceLabs and Dinamap units (96.5 and 90.7 respectively). For diastolic pressure, the converse was true. The standard deviations for all measurement techniques were within normal to upper normal limits. Of special interest, the systolic blood pressures obtained by the oscillometric devices demonstrated smaller standard deviations than either auscultatory (23.9 versus 21.3-SpaceLabs) or direct arterial measurements (24.8 versus 14.9 Dinamap and 23.8 versus 13.3 SpaceLabs). For diastolic blood pressure, however, arterial pressure tracings reflected slightly smaller standard deviations (10.3 versus 11.1-Dinamap and 10.0 versus 11.2-SpaceLabs) when compared with corresponding indirect pressure measurements. Auscultatory and SpaceLabs standard deviation comparisons (13.7 and 13.3 respectively) revealed a slightly smaller standard deviation for the oscillometric diastolic pressure measurement.

Frequency histograms (Figures 3,5,7,9,11,13) and their corresponding scatterplots (Figures 4,6,8,10,12,14) permitted rapid visualization of: (a) direct arterial measurements; and (b) auscultatory and machine performances. Table 5 summarizes these findings.

Table 6 presents the findings and conclusions when the paired t-Test for dependent samples was employed. The only significant difference occurred between arterial and Dinamap

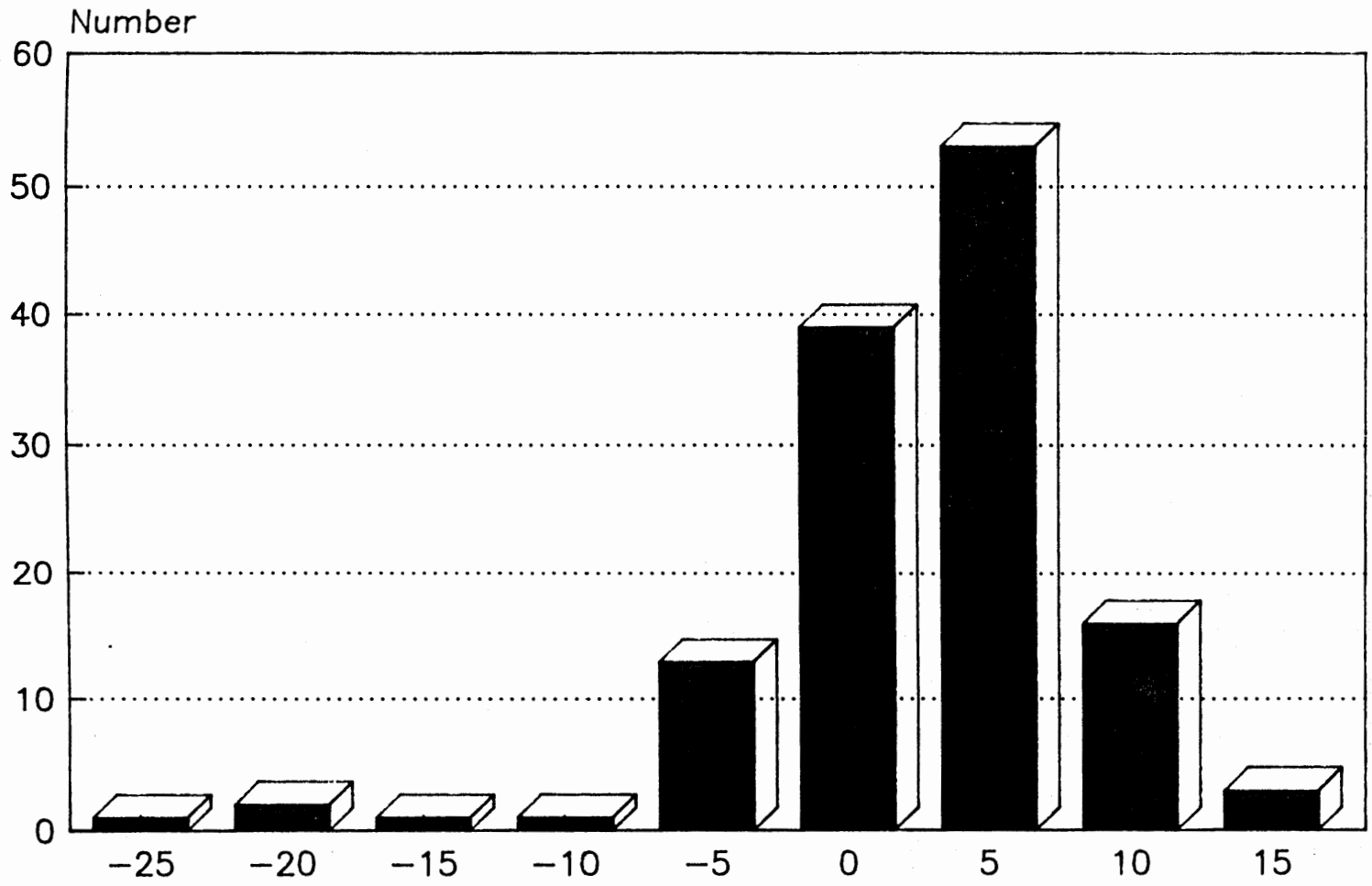

Figure 3. Frequency histogram of deviations from best fit line: Auscultation vs. SpaceLabs systolic blood pressure.

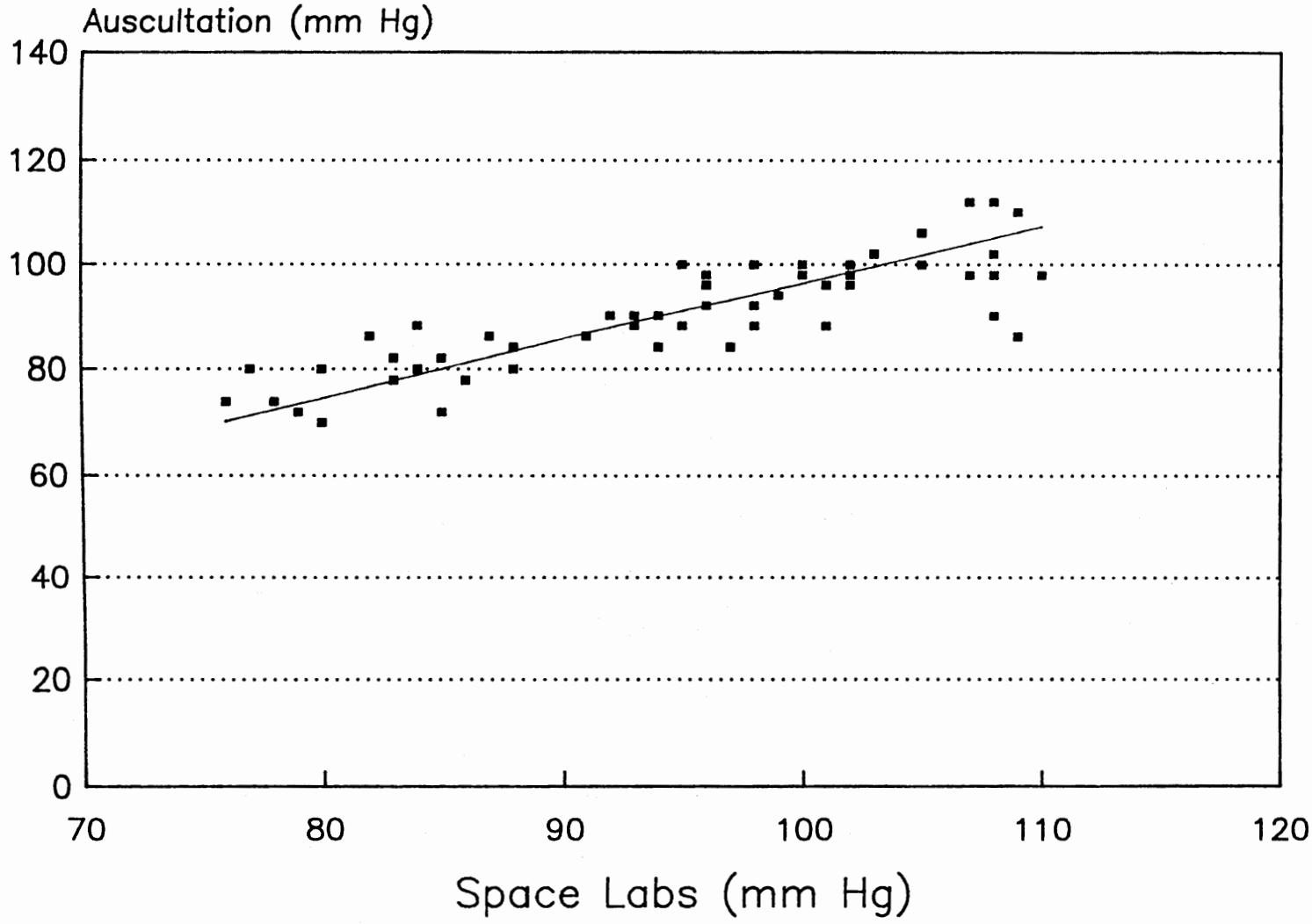

Figure 4. **Scatterplot of auscultation vs. SpaceLabs for systolic blood pressure: Best fit line.**

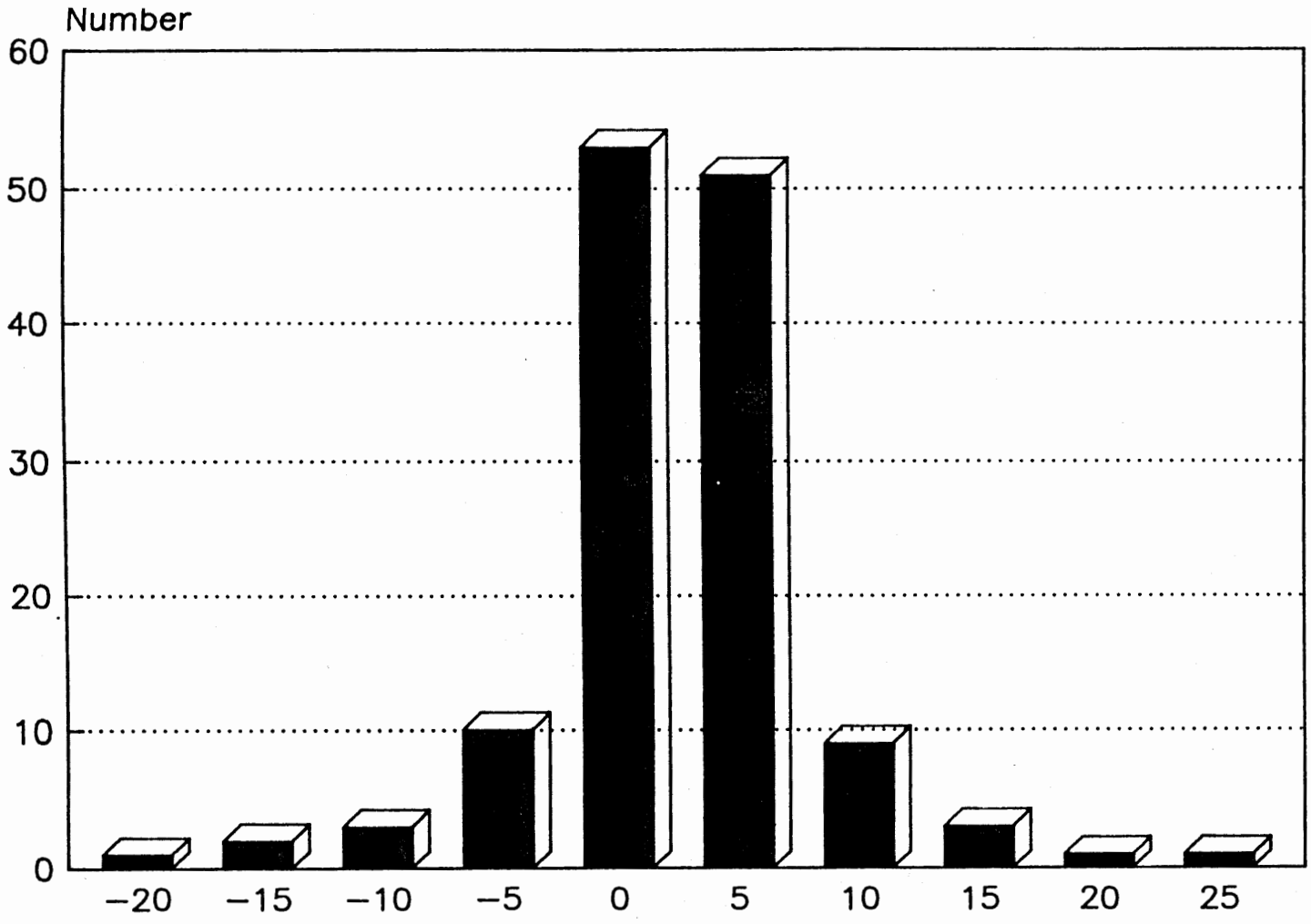

Figure 5. Frequency histogram of deviatons from best fit line: Auscultation vs. SpaceLabs diastolic blood pressure.

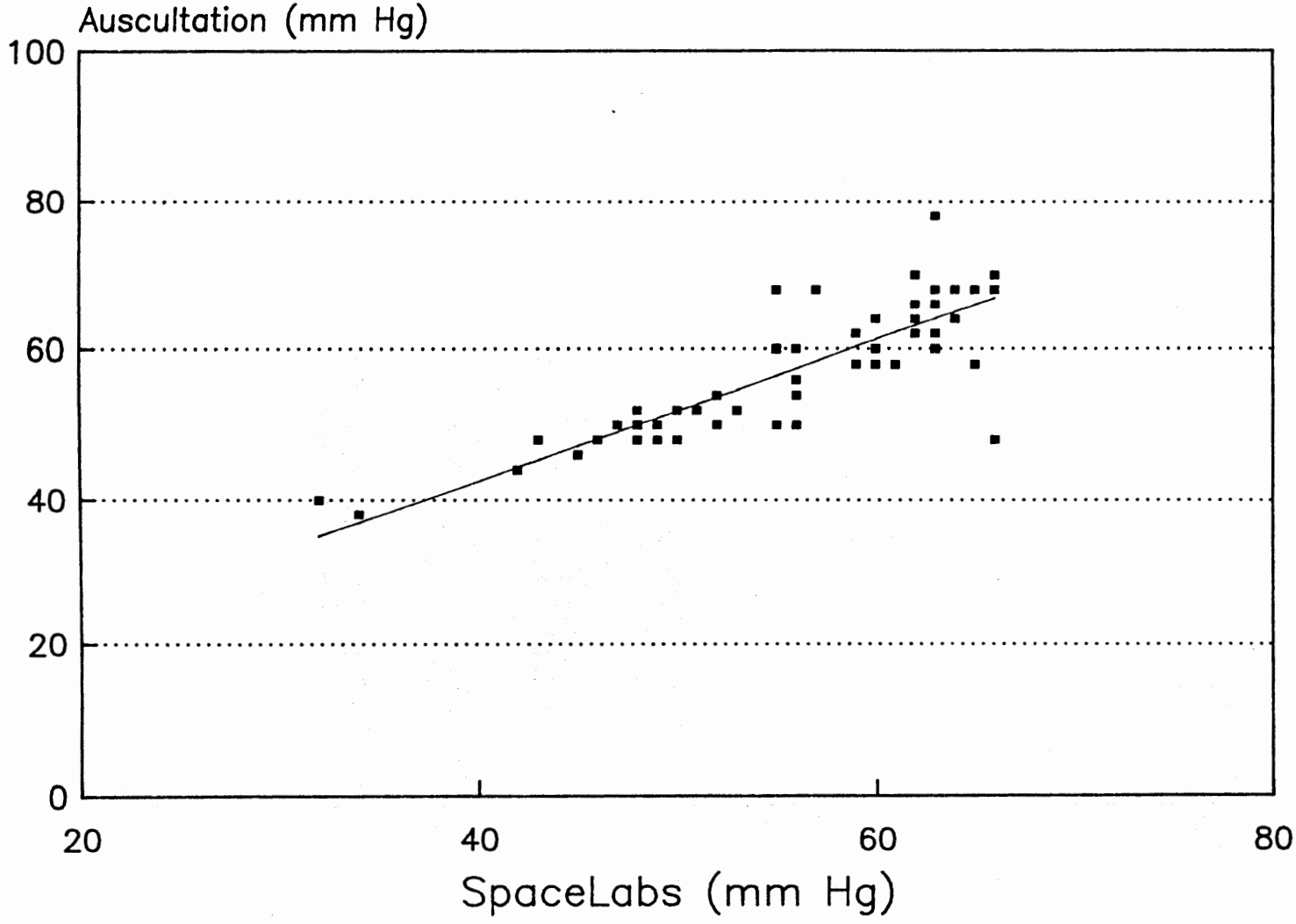

Figure 6. **Scatterplot of auscultation vs. SpaceLabs for diastolic blood pressure: Best fit line.**

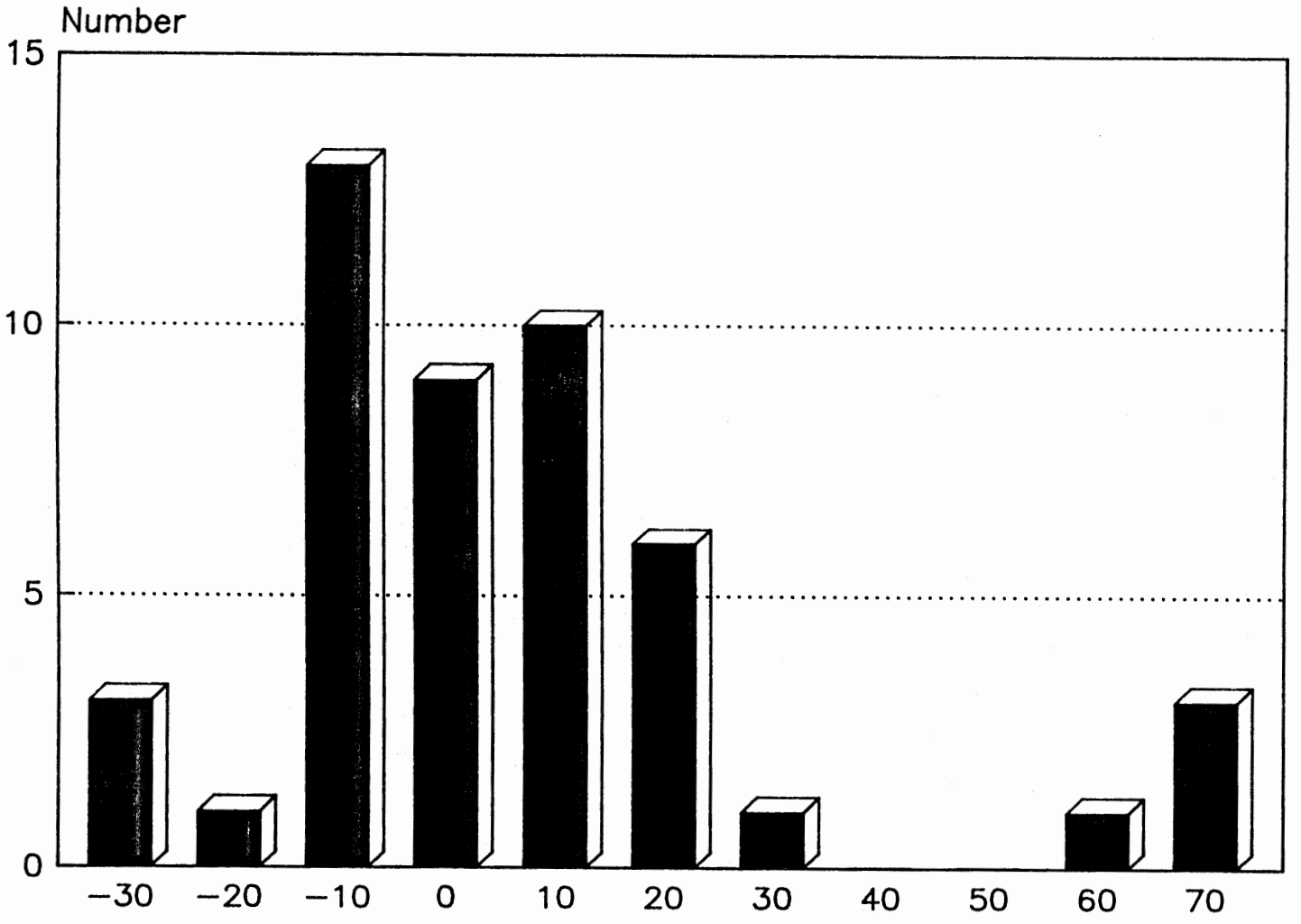

Figure 7. Frequency histogram of deviations from best fit line: Arterial line vs. Dinamap systolic blood pressure.

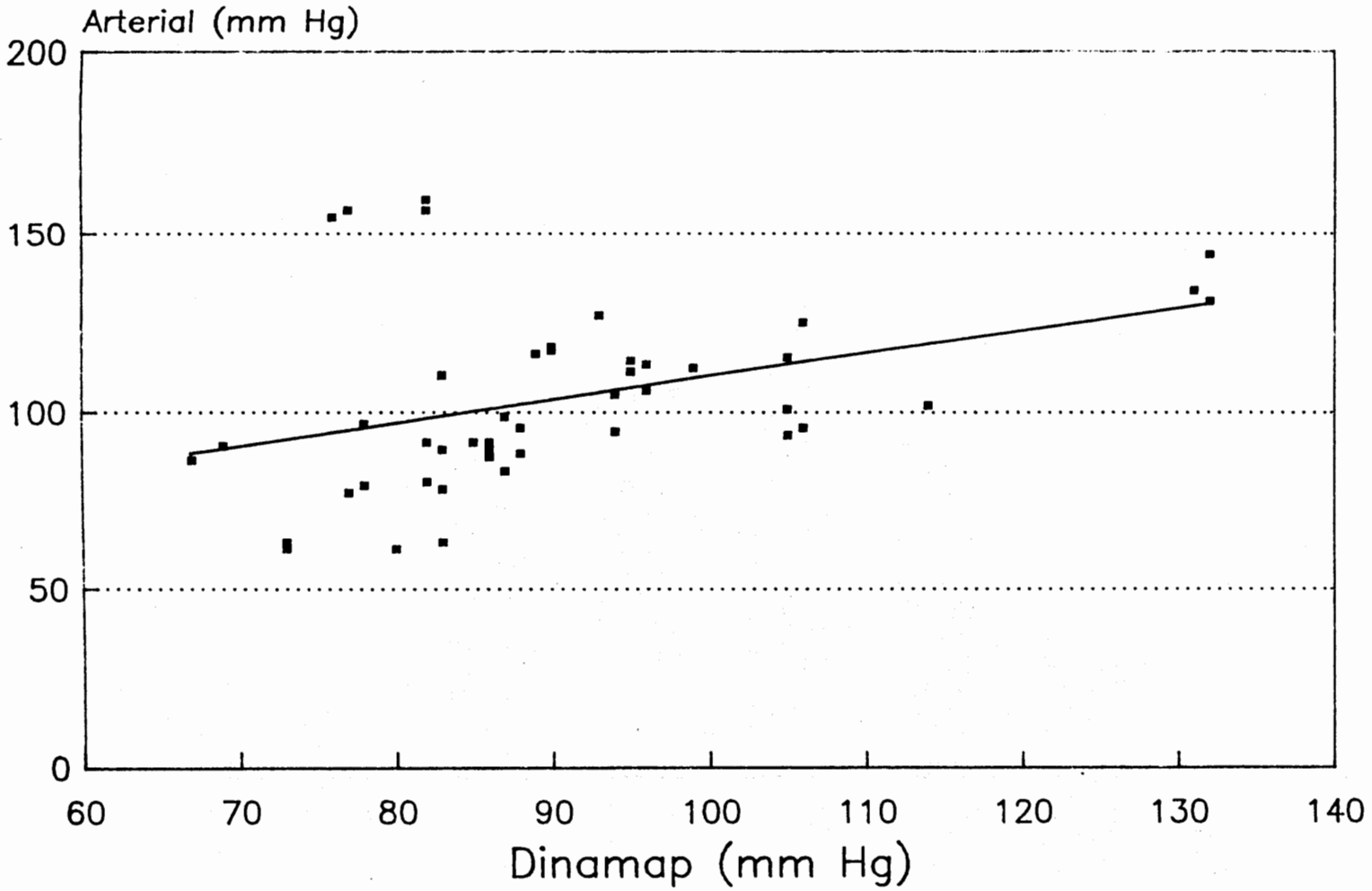

Figure 8. Scatterplot of arterial line vs. Dinamap for systolic blood pressure: Best fit line

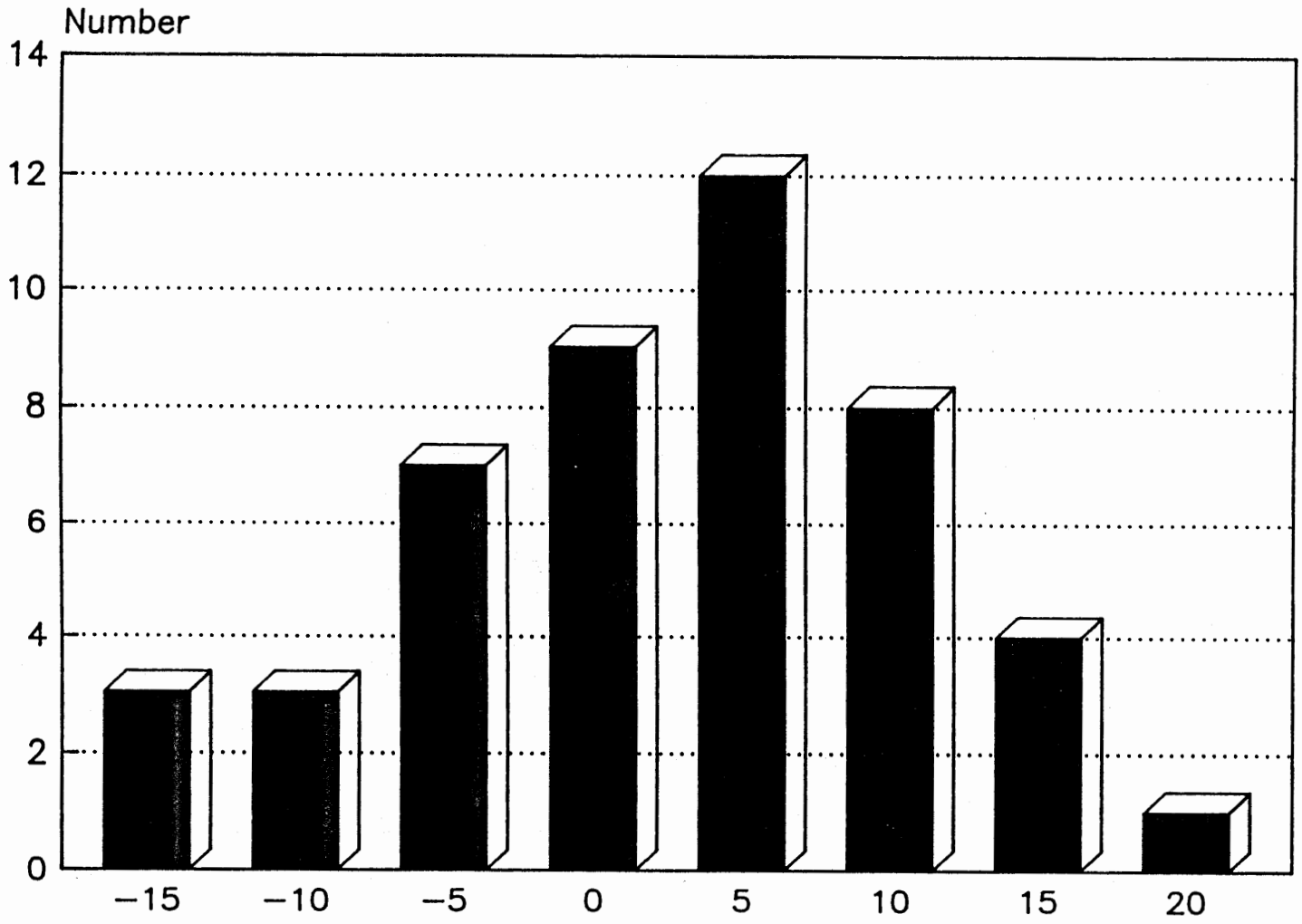

Figure 9. Frequency histogram of deviations from best fit line: Arterial line vs. Dinamap diastolic blood pressure.

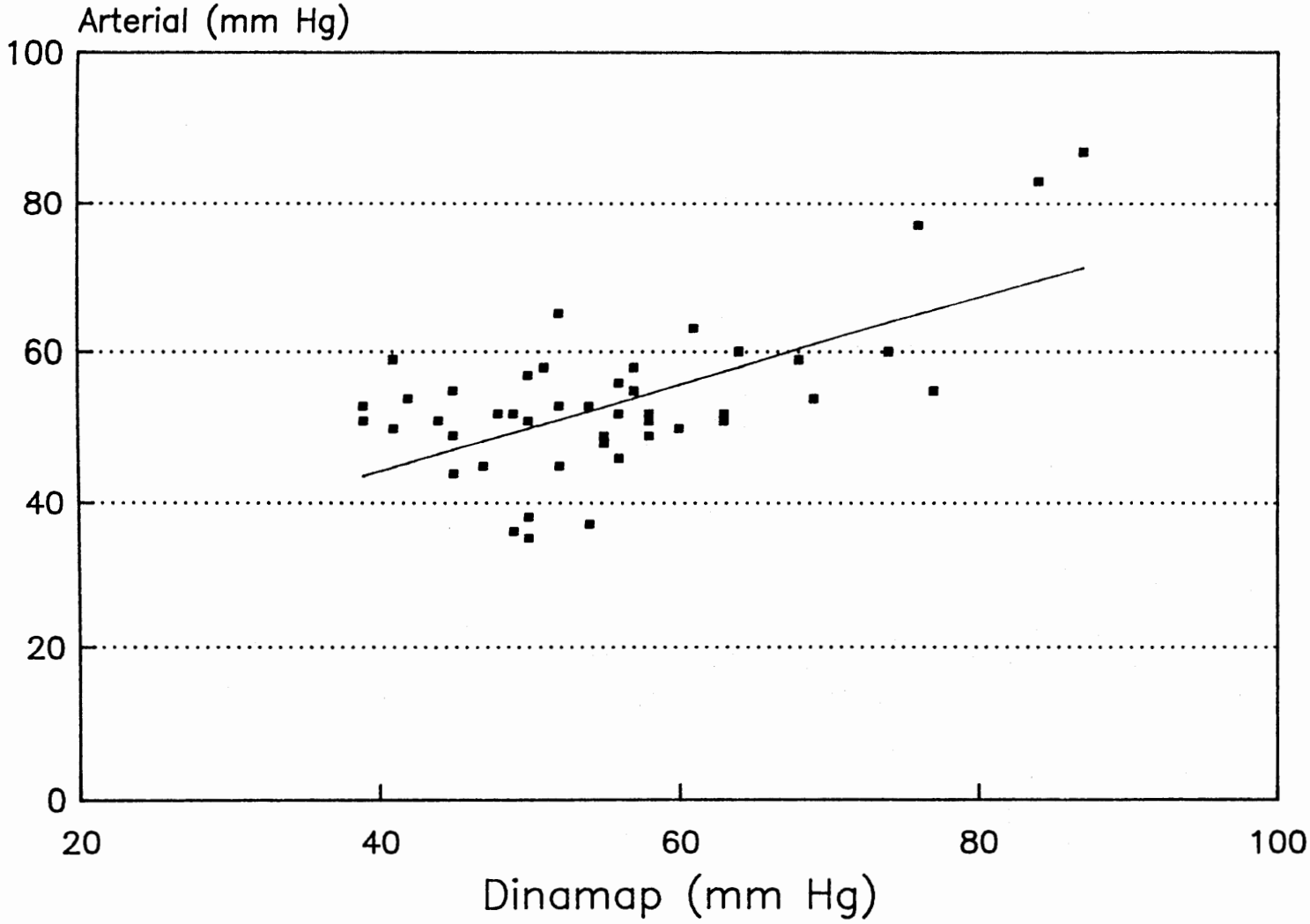

Figure 10. **Scatterplot of arterial line vs. Dinamap for diastolic blood pressure: Best fit line.**

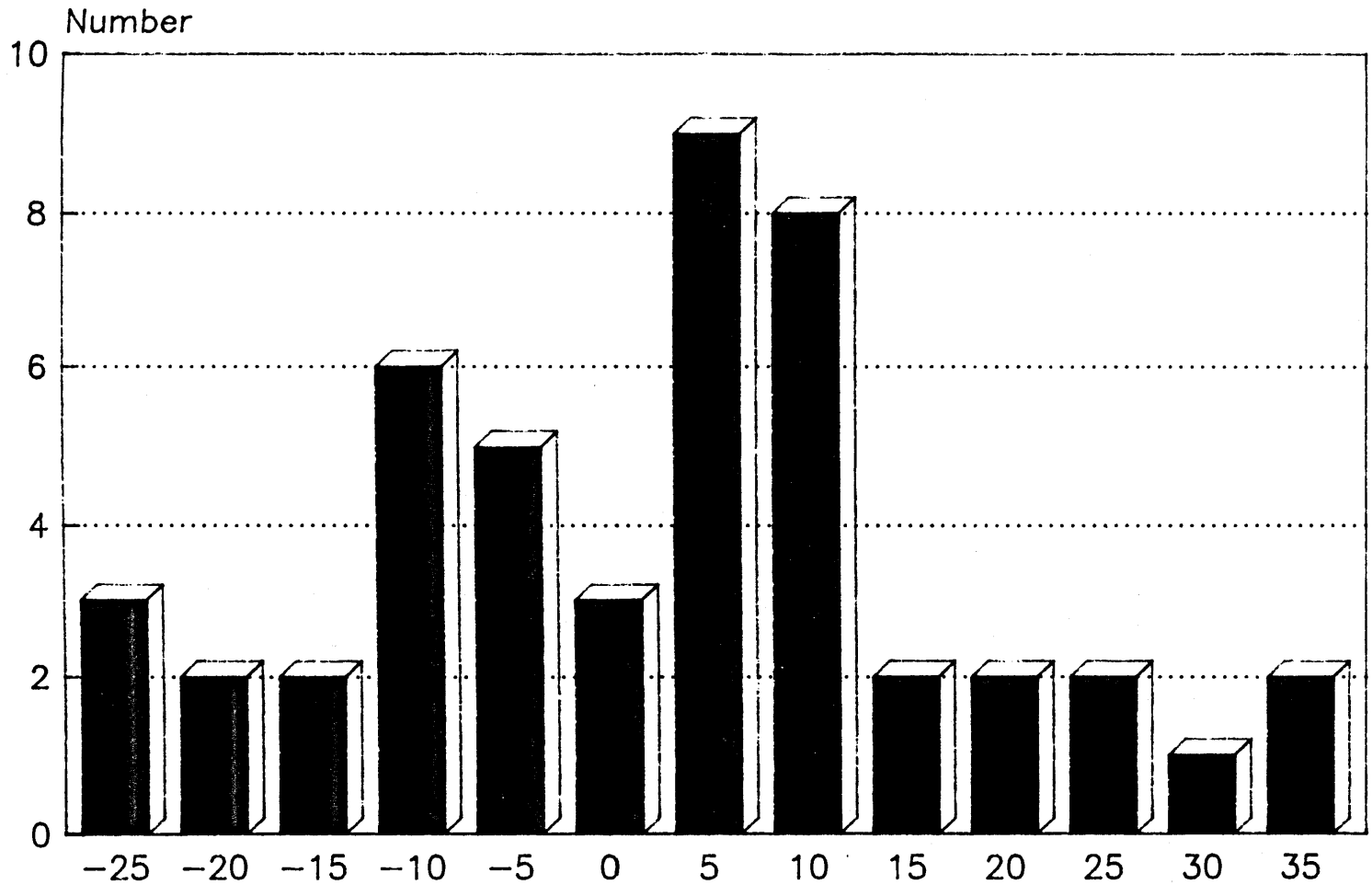

Figure 11. Frequency histogram of deviations from best fit line: Arterial line vs. SpaceLabs systolic blood pressure.

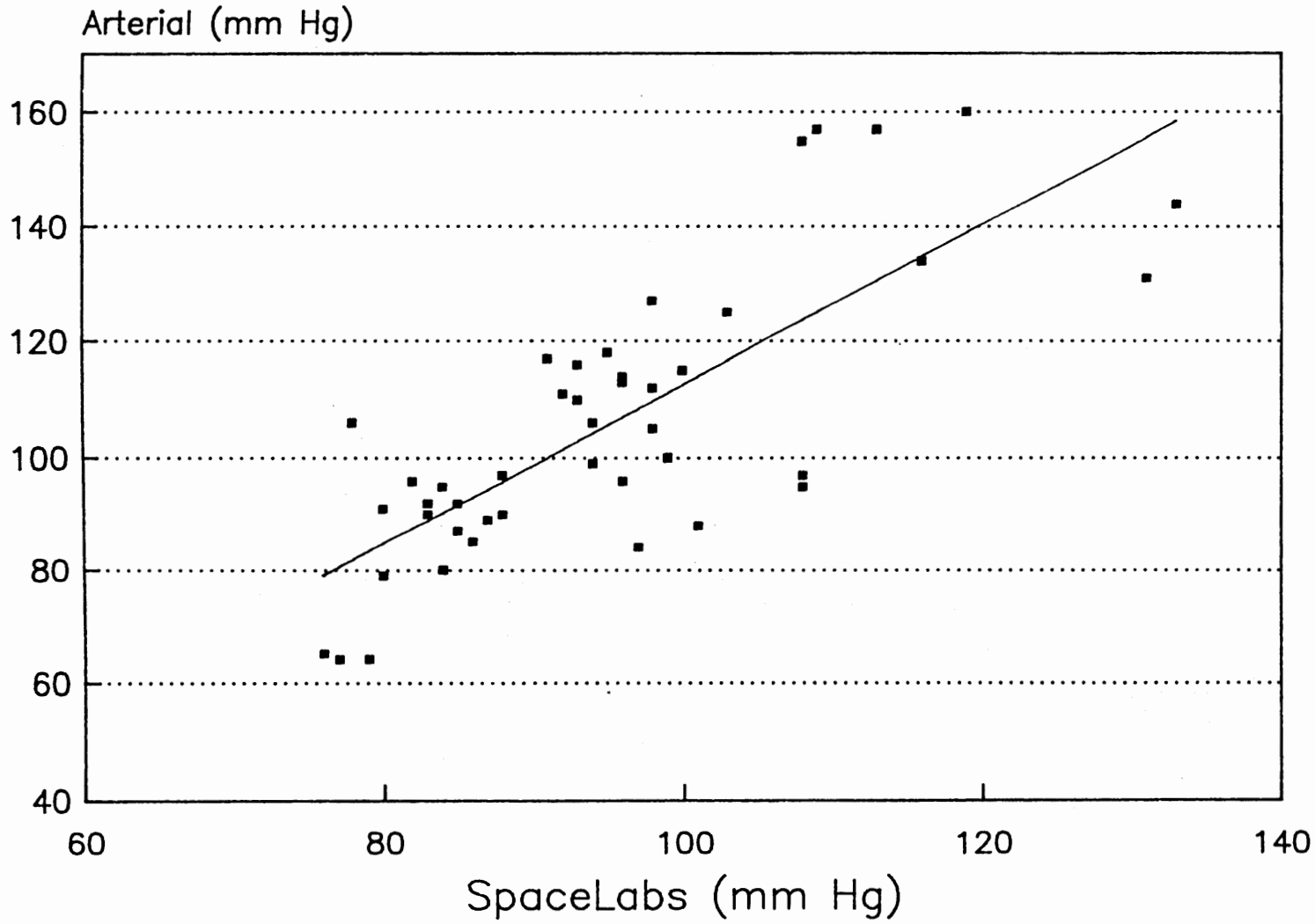

Figure 12. **Scatterplot of arterial line vs. SpaceLabs for systolic blood pressure: Best fit line.**

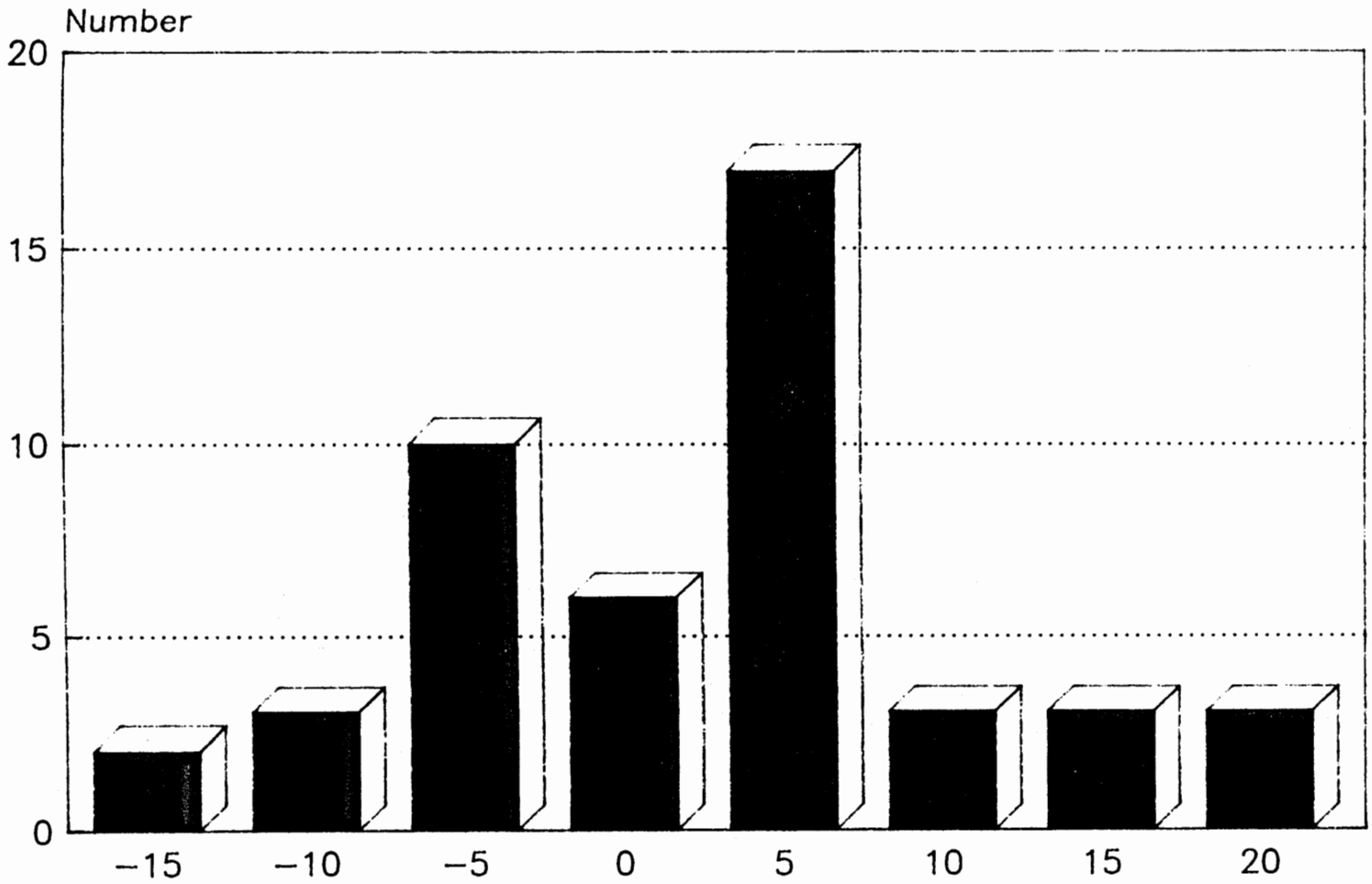

Figure 13. Frequency histogram of deviations from best fit line: Arterial line vs. SpaceLabs diastolic blood pressure.

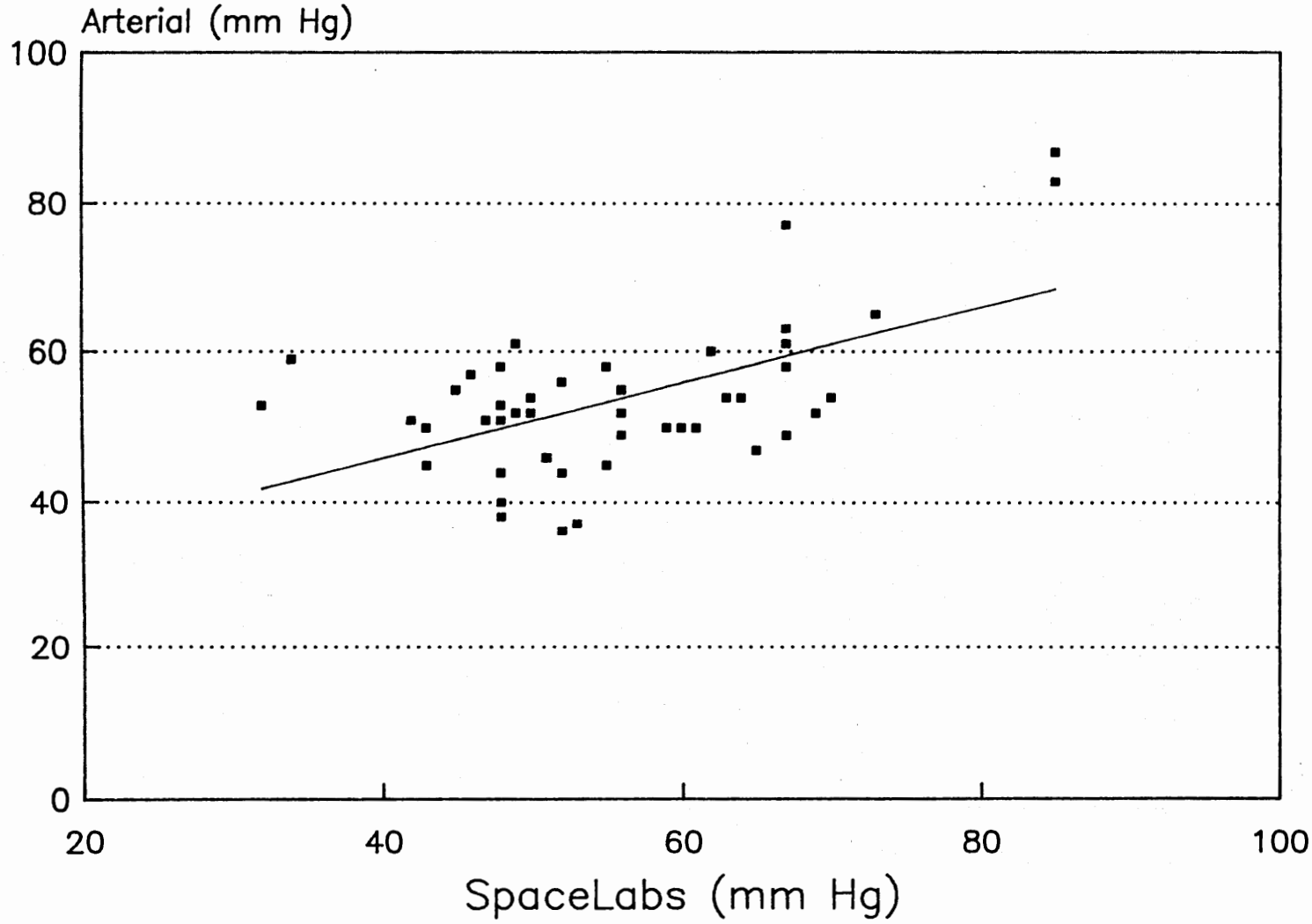

Figure 14. **Scatterplot of arterial line vs. SpaceLabs for diastolic blood pressure: Best fit line.**

Table 5
Summary of Frequency Histograms and Scatterplots Comparing Blood Pressures Obtained by Auscultation, Direct Arterial Measurement, and the SpaceLabs and Dinamap Devices

	Frequency Histogram	Scatterplot Linear Regression Equation and Correlation
SBP: AUSCULTATION VS. SPACELABS -- FIGURES 3 AND 4	125 of 129 measurements or 96.9% were within +/- 15 mm Hg of each other	y = 1.086608x - 12.2802 r = 0.97
DBP: AUSCULTATION VS. SPACELABS -- FIGURES 5 AND 6	123 of 134 measurements or 91.8% were within +/- 10 mm Hg of each other	y = .636095*x + 46.19839 r = 0.91
SBP: ARTERIAL LINE VS. DINAMAP -- FIGURES 7 AND 8	37 of 47 measurements or 78.7% were within +/- 20 mm Hg of each other	y = .575376*x + 21.25778 r = 0.38
DBP: ARTERIAL LINE VS. DINAMAP -- FIGURES 9 AND 10	32 of 47 measurements or 68.1% were within +/- 10 mm Hg of each other	y = .575376*x + 21.25778 r = 0.62
SBP: ARTERIAL LINE VS. SPACELABS -- FIGURES 11 AND 12	17 of 47 measurements or 36.2% were within +/- 10 mm Hg of each other	y = 1.391156*x - 26.5957 r = 0.78
DBP: ARTERIAL LINE VS. SPACELABS -- FIGURES 13 AND 14	39 of 47 measurements or 83% were within +/- 15 mm Hg of each other	y = 0.501193*x +25.85920 r = 0.56

Table 6

The Paired t-Test for Dependent Samples Comparing Blood Pressures Obtained by Auscultation, Direct Arterial Measurement, and the SpaceLabs and Dinamap Devices

Cases	Observed t Value	Critical t Value	df	Alpha Level	Conclusion
SBP: Auscultation vs. SpaceLabs					
129	-8.12	3.291	128	.001	NS
DBP: Auscultation vs. SpaceLabs					
134	-2.31	1.960	133	.05	NS
SBP: Arterial vs. Dinamap					
47	3.84	3.551	46	.001	NS
DBP: Arterial vs. Dinamap					
47	-1.72	2.021	46	.09	S
SBP: Arterial vs. SpaceLabs					
47	3.62	3.551	46	.001	NS
DBP: Arterial vs. SpaceLabs					
47	-2.65	2.423	46	.02	NS

Note. NS = No significant difference; S = significant difference.

diastolic blood pressure measurements as the critical t value exceeded the observed t value at the 0.05 level of significance.

Discussion. As blood pressure increases, oscillometric and auscultatory blood pressure measurements tend to be less than those obtained by direct arterial monitoring (Park & Menard, 1987). This was also a finding of this validation study although further research is required to identify the specific mechanism(s) involved. As blood pressure decreases, arterial vibrations become more difficult to discern via the oscillometric method. This may explain the higher mean diastolic blood pressure values for the Dinamap and SpaceLabs devices when compared with direct arterial mean diastolic measurements.

Although the standard deviations displayed in Table 4 are within acceptable limits, their dispersions from mean pressure values partially reflect the heterogeneity of the subjects. The scatterplots (Figures 4,6,8,10,12,14) and corresponding frequency histograms (Figures 1,3,5,7,9,11,13) permitted rapid evaluation of the data. The smaller systolic and diastolic pressure standard deviations of the SpaceLabs unit versus those acquired by auscultation may have occurred because the oscillometric technique detects pressure oscillation and not Korotkoff sounds. The SpaceLabs device may therefore be more accurate and

sensitive than the auscultatory method in certain situations. In infants and small children, Korotkoff sounds are usually too weak to give accurate readings. Although the intensive care unit subjects were hemodynamically stable and dysrhythmia-free, environmental noise was difficult to control. Therefore, auscultatory accuracy may have been adversely affected. There is also some subjectivity in obtaining a diastolic pressure i.e. when the muffling (Korotkoff 4) versus the disappearance (Korotkoff 5) is detected. This subjectivity is compounded by the persisting debate concerning which Korotkoff sound most accurately reflects diastolic blood pressure. The Second Task Force on Blood Pressure Control in Children (1986) has recommended the fourth Korotkoff sound in children younger than 13 years of age.

Direct arterial systolic pressure standard deviations were greater than their oscillometric counterparts. Direct arterial pressure may have varied because peripheral amplification of systolic blood pressure is: (a) contingent upon catheter location; and (b) predominantly due to summation of the incident and reflected waves (Park & Menard, 1987). Other contributing factors may have been: (a) calibration error by biomedical instrumentation or the intensive care nurse; and (b) tracing pressure measurement error by the research nurse.

Direct arterial diastolic pressure standard deviations, however, were smaller than those determined by the ambulatory blood pressure units. With lower pressure readings, the intra-arterial method may therefore be the most sensitive and accurate technique by which to monitor blood pressure. The small difference in diastolic pressure standard deviation between auscultation (13.7) and SpaceLabs (13.3) may suggest that of the two, the unit is the more accurate and sensitive.

Except for arterial-line versus Dinamap diastolic blood pressure comparisons, other contributing or potential sources of measurement error were: (a) interarm blood pressure differences (Gould et al., 1986); (b) the variable 2 to 7 mm Hg deflation rate of the Dinamap monitor versus the SpaceLabs unit's programmed 4 mm Hg incremental bleed steps; and (c) the oscillometric devices' stepwise deflation rates (Park & Menard, 1986) versus the continuous auscultatory 2 mm Hg per second deflation rate as recommended by the American Heart Association (1980).

This validation study supported arguments that correlation coefficients provide misleading information concerning the precision or accuracy of the different blood pressure measurement methods (Gould et el., 1986; Zezulka, et al., 1985). Arterial line versus Dinamap diastolic blood pressure comparisons (see Table 5, p. 84) indicated a

correlation of 0.62 while the Paired t-Test for Dependent Samples (see Table 6, p. 85) identified a significant difference between the two measurement methods ($p = .09$). The correlation coefficient is a method of association and by definition, the different methods of recording the blood pressure are associated (Gould et al., 1986). However, assessing significance examines the null hypothesis that the readings are unrelated. Because the data are paired readings of the same parameters in the same subjects, this statistic seems appropriate (Zezulka et al., 1985).

Threats to Validity and Reliability

The threats to external validity pertinent to this study are the novelty and experimenter effects. To minimize these threats, the following measures were employed:

1. A minimum of 50 percent of the subjects wore the blood pressure unit for a 48-hour period.

2. To promote sleep, the monitor was programmed to inflate the blood pressure cuff every 20 minutes and to have no audible tone from 12 midnight to 6:00 AM.

3. The investigator conducted the calibration and measurement comparisons as specified in Appendix F.

History and attrition may threaten internal validity. To reduce this possibility, the subjects wore the monitor for two consecutive days. If this was not possible

because of subject preference, he/she wore the device for the second 24-hour period with the interim not exceeding 10 days. The maximum 10 day period was selected so as to reduce the possibility of: (a) drift in circadian patterns; and (b) reintroducing the novelty effect (Reinberg, Andlauer, Buillet, Nicolai, Vieux, & Laport, 1980). Disruptions in normal daily activities i.e., illness, sleep pattern changes, the onset of menstruation, or travel out of the local time zone necessitated a 14-day resynchronization period before reinitiating data collection for a 48-hour period.

Although the computer was programmed to automatically edit measurements not within the default settings established by the investigator and a pediatric cardiologist, all blood pressure measurements were reviewed and edited by the investigator (See Appendix L). All meetings and discussions between the subject and investigator were conducted in a quiet room.

Data Collection

After all necessary consents and demographic information were obtained, data was collected as follows. The investigator and student met at either the children's hospital or health magnet high school. The location was contingent upon subject preference. They met at a previously agreed upon time either before or after

school. The initial meeting lasted approximately one hour during which time, Appendices B and I through L were discussed. The investigator obtained calibration and comparison blood pressure measurements. If the subject was hypertensive, a thigh blood pressure measurement was obtained to rule out coarctation of the aorta.

Four SpaceLabs 90202 Ambulatory Blood Pressure Monitors were employed for data collection. Each unit was programmed to inflate the cuff: (a) every 10 minutes from 0600 to 12 midnight; and (b) every 20 minutes from midnight to 0600. The SpaceLabs monitor automatically measured and recorded heart rate and systolic, diastolic, and mean arterial pressures at these intervals. The subject returned after one 24-hour period during which time: (a) unit calibration and comparison measurements were repeated; (b) the device was downloaded into an IBM compatible Zenith Z-183 PC; (c) the Activity Diary was reviewed; (d) the student's comments and criticisms were discussed; and (e) heart rate and blood pressure measurements were displayed on the computer screen for the investigator and subject to review. This second meeting lasted approximately 30 minutes. At it's conclusion, the student was asked if he/she was interested in wearing the unit for an additional 24 hours and why this was important. If preferred, the ambulatory blood pressure monitoring device was not worn on consecutive

days. However, the interim period between the two days of data collection, did not exceed 10 days. This permitted circadian rhythm assessment without introducing the threat of time, which could have invalidated the findings.

During the second day of data collection, a similar protocol was followed. For participating the entire 24-hour period, subjects were paid $15. If he/she decided to wear the blood pressure unit for another 24 hours, the student received an additional $15.

Physical activity is a difficult variable to quantify and is a confounding effect in this field study (Polit & Hungler, 1983). In an Activity Diary, subjects documented the time frames when they were: (a) sleeping; (b) sitting; and (c) changing activity levels i.e., running or climbing more than two flights of stairs. They were also asked to note any dizziness or lightheadedness in the "Comments" section indicating: (a) the symptom's duration; and (b) what was done, if anything, to resolve it. The Activity Diary facilitated data interpretation and documented the "baseline" and "resting" measurements which were employed to ascertain any circadian differences between the hypertensive and normotensive students.

Pilot Study

The investigator conducted a pilot study composed of seven subjects. Demographic information describing this

sample is presented in Table 7.

Table 7

Demographic Information -- Pilot Study

Subject #	Category	Age (yrs)	Sex	Ethnicity	Height (cm)	Weight (kg)
1	N	17	F	Black	160.0	72.9
2	N	15	F	Black	162.6	65.4
3	H	17	F	Black	157.4	47.2
4	H	17	M	Hispanic	182.8	100.0*
5	N	14	F	Black	157.4	51.1
6	N	16	M	Black	181.6	82.2*
7	N	14	M	Black	168.9	83.4*
MAX:		17			182.8	100.0
MIN:		14			157.4	47.2
Mean:		15.7			167.2	71.7
Standard Dev.:		1.3			10.1	17.4

Note. H = High blood pressure levels
N = Normal blood pressure levels
* Indicates those weights greater than the age/sex-specific 90th percentile values

The pilot study was conducted identically to the research investigating cardiovascular circadian rhythmicity between hypertensive and normotensive adolescents with the following exceptions:

1. Blood pressure and heart rate measurements simultaneously obtained by the SpaceLabs unit and the investigator when the student was connected to and disconnected from the monitor were not recorded. Rather, only the Calibration Checklist was employed (see Appendix H).

2. The investigator did not demonstrate how to page

her via the beeper.

Treatment of Data

Edited heart rate and blood pressure measurements were coded and logged on the investigator's IBM compatible Zenith Z-183 PC. The data with header information were then sent via floppy disk to Dr. Halberg's computer facilities at the Chronobiology Laboratories, University of Minnesota (Minneapolis). The cosinor analysis program (Halberg, 1969) calculates the best unbiased estimates of population parameters such as acrophases (peaks), mesors (means), amplitudes (magnitude of variation), and percent rhythm for each variable. It also identifies synchrony or dysynchrony among the rhythms. Specifically, the analysis yields the variables phase relationships with each other and with predicted norms for each subject.

Analysis utilizing the cosinor curve provides two additional parameters for each variable. The first parameter is the rhythm-adjusted mean, or mesor. Mesor is defined as the mean of the cosine curve fitted to a rhythmic variable. The mesor is equal to the mean of the determined values if these have been sampled at regular intervals for an integral number of periods, as was done in this study. The second parameter is the amplitude of the rhythm of the variables (Halberg, 1969). The mean, mesor, and amplitude describe the level of the variable's rhythm and

the degree of fluctuation (Halberg, 1953; Halberg et al., 1972; Kaukkari, Duke, Halberg, & Joung-Kuen, 1974). The mean percentage of rhythm depicts now much of the data is explained in a fitted curve. The higher the percentage of rhythm, the more likely the variable is tightly coupled to a driving oscillator. The lower the percentage of rhythm, the less likely the variable is tightly coupled to the driving oscillator. It is then said to depict loose coupling which may result in dysynchrony. The overall circadian hyperbaric index (HBI) may also be calculated employing a cosine curve of best fit (Halberg, Drayer, Cornélissen, & Weber, 1984).

CHAPTER IV

ANALYSIS OF DATA

This quantitative-descriptive, hypothesis-testing field study (Kerlinger, 1973; Polit & Hungler, 1983) was conducted to determine if there were significant differences in cardiovascular circadian rhythmicity between normotensive and hypertensive adolescents. Cosinor analysis (Halberg, 1969) was employed to calculate the best unbiased estimates of population parameters such as mesors (means), amplitudes (magnitude of variation), acrophases (peaks), and mean percent rhythm for heart rate and systolic/diastolic blood pressures. It also identified: (a) synchrony or dysynchrony among the rhythms; and (b) the overall circadian hyperbaric index (HBI). Demographic information was obtained to facilitate data analysis. The Space Labs 90202 Monitor Validation Study results are also summarized.

Description of Samples

Table 8 displays the demographic information of the 12 male and 11 female adolescents participating in this circadian rhythm study. The hypertensive sample was composed of seven men and six women ranging in age from 15 to 18 years (mean 16.1 ± 1.14). According to ethnicity, ten were black (four males and six females), two men were Hispanic, and one male was Caucasian. Their heights ranged from 157.4 to 182.8 cm. (mean 170.8 ± 8.37) while

Table 8

Demographic Information -- Circadian Rhythm Study

SUBJECT #	CATEGORY	AGE (years)	SEX	ETHNICITY	HEIGHT (cm)	WEIGHT (kg)
1	H	17	M	Hispanic	182.8	100.0*
2	N	17	M	Hispanic	168.3	57.3
3	H	17	F	Black	157.4	47.2
4	N	17	F	Black	160.0	72.9
5	H	15	F	Black	161.2	61.3
6	N	15	F	Black	157.2	55.4
7	H	15	M	Black	175.2	75.6*
8	N	15	M	Black	174.0	60.0
9	H	15	M	Caucasian	176.5	69.7
10	N	15	M	Caucasian	165.1	46.8
11	H	15	F	Black	160.0	52.7
12	N	15	F	Black	160.0	70.2*
13	H	15	F	Black	172.7*	60.6
14	N	15	F	Black	162.1	46.2
15	H	15	F	Black	164.9	86.8*
16	N	15	F	Black	160.3	55.2
17	H	16	M	Black	182.8	100.0*
18	N	16	M	Black	177.8*	97.0*
19	H	17	M	Black	179.0	100.9*
20	N	17	M	Black	172.7	64.3
21	H	18	M	Black	176.5	61.8
22	H	18	M	Hispanic	165.8	62.9
23	H	16	F	Black	166.3	55.9
COMBINED DATA:						
Maximum Value:		18.0			182.8	100.9
Minimum Value:		15.0			157.2	46.2
Mean:		15.9			168.6	67.8
Standard Deviation:		1.1			8.1	17.2
HYPERTENSIVE:						
Maximum Value:		18.0			182.8	100.9
Minimum Value:		15.0			157.4	47.2
Mean:		16.1			170.8	71.9
Standard Deviation:		1.1			8.4	18.2
NORMOTENSIVE:						
Maximum Value:		17.0			177.8	97.0
Minimum Value:		15.0			157.7	46.2
Mean:		15.7			165.7	62.5
Standard Deviation:		0.9			6.7	14.2

Note. H = High blood pressure levels; N = Normal blood pressure levels; * = Indicates those heights and weights greater than the age/sex-specific 90th percentile values.

weights were from 47.2 to 100.9 kg (mean 71.9 ± 18.23). Five students with high blood pressure levels (one Hispanic and three black males and one black female) were greater than their age/sex-specific 90th percentile weight values (Second National Heart, Lung, and Blood Institute's Task Force on Blood Pressure Control in Children, 1986). However, none of these five students were taller than their corresponding age/sex specific 90th percentile height measurements.

The normotensive sample consisted of five men and five women ranging in age from 15 to 17 years (mean 15.7 ± 0.90). Eight students were black with only one male student each representing the Hispanic and Caucasian races. Their heights ranged from 157.7 to 177.8 cm (mean 165.7 ± 6.71) while weights were from 46.2 to 97.0 kg. (mean 62.5 ± 14.18). Two normotensive students (one black female and one black male) weighed more than individuals in their age/sex-specific 90th percentile category. The male was also taller than other adolescents in his age/sex-specific 90th percentile group.

All students had to meet the following delimitations in order to be considered for study participation:

1. day-active people.
2. 13 to 19 years old (inclusive).
3. enrolled in a metropolitan health magnet high

school.

4. able to read and comprehend English.

5. if hypertensive, primary type hypertension only.

6. dysrhythmia-free.

7. not pregnant or taking birth control pills.

8. if normotensive, no family history of hypertension.

9. no history of diabetes or other hormonal problems, renal disease, or cardiac disease (including aortic incompetence and coarctation of the aorta).

No hypertensive adolescent was taking antihypertensive medication. One hypertensive and one normotensive subject were asthmatic but did not require medication two weeks prior nor during data collection. The stratified random normotensive group was matched with ten hypertensive students for age, sex, and ethnicity. Hypertensive subjects 21, 22, and 23 were similarly matched with three normotensive participants from the Maryland blood pressure study (Brenner et al., in press).

Findings

The data generated were analyzed in an attempt to quantify the daily or 24-hour fluctuations of systolic/diastolic blood pressure and heart rate in hypertensive and normotensive high school students. Specific data will be presented then discussed within the context of the null hypotheses.

Rhythmometric data for adolescent systolic/diastolic blood pressures and heart rates are displayed in Tables 9 through 11. Twelve heart rate values were first edited from 9 profiles as were 7 systolic and diastolic measurements each from 7 different profiles. With the fit of two harmonics i.e., the fundamental 24-hour cosine curve of best fit and the first 12-hour harmonic, all but two systolic blood pressure profiles yielded a p value below 5 % for the rejection of this composite model. In other words, except for Subject 17 (p = .780) and the second profile of Subject 8 (p =.482), the possibility that the data varied by chance was below the 5% level (see Table 9). Subject 8's second profile yielded only 42 observations covering 12 hours. With Subject 17, most of the night data were missing. Despite these omissions, the model reached the 6% level of statistical significance. All diastolic blood pressure and heart rate profiles were fitted by the combined 24- and 12-hour model (see the p values displayed in Tables 10 and 11).

Hypothesis 1 stated: There are no significant differences in systolic/diastolic blood pressure mesors between normotensive and hypertensive adolescents. The null hypothesis of no significant differences was not supported. Table 12 presents the p values for combined data comparing the hypertensive/normotensive pairs matched

Table 9

Rhythmometric Summary -- Systolic Blood Pressure

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A +/- s.e.	(95% ci)	ACROPHASE (phi) +/- s.e	(95% ci)
			125.430 1.163						
1-H	1	24		45	<0.001	14.374 1.600	(11.24,17.51)	-239 7	(-226,-252)
		12		3	0.049	3.957 1.627	(0.77, 7.15)	-255 24	(-208,-301)
		overall		48	<0.001				
			119.076 1.336						
1-H	2	24		41	<0.001	14.973 1.794	(11.46,18.49)	-247 8	(-232,-262)
		12		14	<0.001	9.572 1.957	(5.74,13.41)	-309 11	(-287,-331)
		overall		55	<0.001				
			107.168 0.802						
2-N	1	24		47	<0.001	11.416 1.118	(9.22,13.61)	-274 6	(-263,-285)
		12		3	0.004	3.805 1.129	(1.59, 6.02)	-331 17	(-298, -4)
		overall		51	<0.001				
			111.172 0.744						
2-N	2	24		40	<0.001	9.206 1.044	(7.16,11.25)	-276 7	(-263,-289)
		12		0	0.126	2.129 1.041	(0.09, 4.17)	-311 28	(-257, -6)
		overall		40	<0.001				
			114.714 0.749						
3-H	1	24		29	<0.001	6.591 1.029	(4.57, 8.61)	-210 9	(-192,-229)
		12		13	0.001	4.198 1.011	(2.22, 6.18)	-342 15	(-313, -12)
		overall		42	<0.001				
			113.089 0.883						
3-H	2	24		35	<0.001	9.355 1.154	(7.09,11.62)	-220 8	(-204,-236)
		12		2	0.155	2.430 1.255	(-0.03, 4.89)	-292 29	(-236,-348)
		overall		37	<0.001				
			113.617 0.700						
4-N	1	24		45	<0.001	9.517 0.918	(7.72,11.32)	-225 6	(-213,-238)
		12		2	0.023	2.664 1.013	(0.68, 4.65)	-237 21	(-197,-277)
		overall		47	<0.001				

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 9

Rhythmometric Summary -- Systolic Blood Pressure (cont.)

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A +/- s.e.	(95% ci)	ACROPHASE (phi) +/- s.e	(95% ci)
			115.844 0.889						
4-N	2	24		16	<0.001	6.445 1.248	(4.00, 8.89)	-258 11	(-237,-280)
		12		30	<0.001	8.833 1.306	(6.27,11.39)	-284 8	(-269,-300)
		overall		46	<0.001				
			120.719 1.180						
5-H	1	24		21	<0.001	7.831 1.854	(4.20,11.46)	-270 10	(-251,-289)
		12		0	0.930	0.564 1.499	(-2.37, 3.50)	-119 157	(-171, -68)
		overall		22	<0.001				
			104.218 0.683						
6-N	1	24		3	0.053	2.496 0.941	(0.65, 4.34)	-219 23	(-174,-263)
		12		18	<0.001	4.785 0.961	(2.90, 6.67)	-277 12	(-254,-299)
		overall		21	<0.001				
			102.556 0.995						
6-N	2	24		56	<0.001	12.873 1.370	(10.19,15.56)	-219 7	(-206,-232)
		12		0	0.141	2.824 1.464	(-0.04, 5.69)	-327 28	(-272, -22)
		overall		55	<0.001				
			129.403 1.060						
7-H	1	24		11	0.005	5.334 1.411	(2.57, 8.10)	-236 17	(-203,-268)
		12		3	0.136	3.221 1.590	(0.11, 6.34)	-273 24	(-226,-321)
		overall		14	0.013				
			126.385 0.878						
7-H	2	24		12	0.002	4.707 1.191	(2.37, 7.04)	-233 16	(-202,-263)
		12		7	0.017	3.709 1.251	(1.26, 6.16)	-248 19	(-211,-285)
		overall		19	0.001				
			120.876 0.921						
8-N	1	24		11	0.008	4.182 1.323	(1.59, 6.78)	-15 18	(-340, -50)
		12		16	0.001	4.895 1.261	(2.42, 7.37)	-270 16	(-240,-301)
		overall		27	<0.001				

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 9

Rhythmometric Summary -- Systolic Blood Pressure (cont.)

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A	+/- s.e.	(95% ci)	ACROPHASE (phi)	+/- s.e	(95% ci)
			123.968 11.522								
8-N	2	24		4	0.971	3.923	16.199	(-27.83,35.67)	-260	81	(-101, -59)
		12		5	0.949	2.097	8.574	(-14.71,18.90)	-184	105	(-339, -29)
		overall		9	0.482						
			120.511 0.805								
9-H	1	24		69	<0.001	17.953	1.049	(15.90,20.01)	-250	4	(-243,-258)
		12		2	0.196	2.051	1.109	(-0.12, 4.23)	-34	31	(-333, -96)
		overall		71	<0.001						
			121.878 1.021								
9-H	2	24		54	<0.001	18.100	1.403	(15.35,20.85)	-259	5	(-249,-268)
		12		13	<0.001	9.813	1.391	(7.09,12.54)	-16	9	(-359, -33)
		overall		67	<0.001						
			113.884 0.775								
10-N	1	24		55	<0.001	12.958	1.070	(10.86,15.05)	-234	5	(-224,-244)
		12		6	<0.001	4.937	1.119	(2.74, 7.13)	-289	12	(-265,-313)
		overall		61	<0.001						
			114.608 0.926								
10-N	2	24		38	<0.001	10.701	1.283	(8.19,13.22)	-213	7	(-199,-227)
		12		19	<0.001	7.437	1.312	(4.86,10.01)	-258	10	(-238,-278)
		overall		57	<0.001						
			116.861 1.012								
11-H	1	24		15	<0.001	6.345	1.361	(3.68, 9.01)	-265	13	(-240,-290)
		12		5	0.007	4.600	1.365	(1.92, 7.27)	-285	15	(-255,-315)
		overall		19	<0.001						
			115.414 0.738								
11-H	2	24		18	<0.001	6.385	0.961	(4.50, 8.27)	-236	10	(-216,-255)
		12		17	<0.001	5.795	1.018	(3.80, 7.79)	-234	10	(-315,-354)
		overall		35	<0.001						

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 9

Rhythmometric Summary -- Systolic Blood Pressure (cont.)

Subject		Period				AMPLITUDE			ACROPHASE		
#	Day	(hours)	Mesor +/- s.e	pr	p	A +/- s.e.	(95% ci)		(phi) +/- s.e		(95% ci)
			111.549 0.859								
12-N	1	24		32	<0.001	7.617	1.187	(5.29, 9.94)	-244	9	(-226,-262)
		12		5	0.097	2.485	1.128	(0.27, 4.70)	-356	29	(-299, -54)
		overall		37	<0.001						
			107.697 0.632								
12-N	2	24		30	<0.001	7.192	0.848	(5.53, 8.85)	-214	8	(-199,-229)
		12		10	<0.001	4.791	0.906	(3.02, 6.57)	-298	10	(-278,-319)
		overall		40	<0.001						
			121.512 0.905								
13-H	1	24		29	<0.001	8.509	1.234	(6.09,10.93)	-259	9	(-241,-276)
		12		0	0.691	1.127	1.244	(-1.31, 3.56)	-245	66	(-115, -14)
		overall		29	<0.001						
			120.122 0.993								
13-H	2	24		16	<0.001	5.718	1.525	(2.73, 8.71)	-230	14	(-204,-257)
		12		3	0.093	3.361	1.485	(0.45, 6.27)	-277	23	(-232,-321)
		overall		19	<0.001						
			110.602 0.777								
14-N	1	24		42	<0.001	8.239	1.095	(6.09,10.39)	-250	8	(-235,-265)
		12		3	0.071	2.411	0.991	(0.47, 4.35)	-350	26	(-299, -40)
		overall		45	<0.001						
			129.864 1.112								
15-H	1	24		7	0.056	3.852	1.559	(0.80, 6.91)	-317	23	(-271, -3)
		12		23	<0.001	7.032	1.629	(3.84,10.22)	-70	11	(-48, -92)
		overall		30	<0.001						
			128.474 1.091								
15-H	2	24		38	<0.001	9.954	1.429	(7.15,12.76)	-273	9	(-255,-291)
		12		7	0.028	4.477	1.399	(1.73, 7.22)	-46	21	(-5, -87)
		overall		45	<0.001						

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 9

Rhythmometric Summary -- Systolic Blood Pressure (cont.)

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A +/- s.e.	(95% ci)	ACROPHASE (phi) +/- s.e	(95% ci)
			108.460 0.729						
16-N	1	24		0	0.746	0.747 1.034	(-1.28, 2.77)	-106 78	(-313,-259)
		12		22	<0.001	5.102 1.031	(3.08, 7.12)	-145 11	(-123,-168)
		overall		22	<0.001				
			127.621 1.626						
17-H	1	24		0	0.780	1.185 1.603	(-1.96, 4.33)	-37 124	(-154,-279)
		12		15	0.077	4.430 1.388	(1.71, 7.15)	-136 25	(-86,-185)
		overall		14	0.062				
			121.679 0.984						
18-N	1	24		10	0.018	4.077 1.440	(1.25, 6.90)	-199 19	(-161,-237)
		12		5	0.099	2.912 1.336	(0.29, 5.53)	-327 28	(-273, -22)
		overall		15	0.026				
			128.316 0.829						
19-H	1	24		31	<0.001	9.276 1.107	(7.11,11.45)	-216 8	(-201,-231)
		12		16	<0.001	6.787 1.181	(4.47, 9.10)	-341 10	(-322, -1)
		overall		47	<0.001				
			128.552 0.896						
19-H	2	24		32	<0.001	8.839 1.281	(6.33,11.35)	-250 8	(-234,-266)
		12		7	0.011	4.072 1.282	(1.56, 6.59)	-301 18	(-267,-336)
		overall		39	<0.001				
			113.563 0.895						
20-N	1	24		0	0.088	3.120 1.170	(0.83, 5.41)	-205 24	(-157,-253)
		12		34	<0.001	9.188 1.196	(6.84,11.53)	-245 8	(-230,-260)
		overall		34	<0.001				
			122.788 1.044						
21-H	1	24		38	<0.001	12.424 1.536	(9.41,15.43)	-227 7	(-214,-240)
		12		30	<0.001	10.282 1.682	(6.99,13.58)	-335 8	(-320,-350)
		overall		68	<0.001				

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 9

Rhythmometric Summary -- Systolic Blood Pressure (cont.)

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A +/- s.e.	(95% ci)	ACROPHASE (phi) +/- s.e	(95% ci)
			123.293 1.004						
21-H	2	24		52	<0.001	13.003 1.437	(10.19,15.82)	-289 6	(-277,-301)
		12		5	0.008	4.362 1.471	(1.48, 7.25)	-346 18	(-311, -21)
		overall		57	<0.001				
			124.940 0.973						
22-H	1	24		33	<0.001	11.566 1.399	(8.82,14.31)	-266 7	(-253,-279)
		12		17	<0.001	7.663 1.328	(5.06,10.27)	-23 10	(-3, -42)
		overall		50	<0.001				
			118.079 0.850						
23-H	1	24		31	<0.001	6.281 1.197	(3.94, 8.63)	-222 11	(-201,-243)
		12		2	0.262	1.790 1.252	(-0.66, 4.24)	-35 37	(-321,-108)
		overall		32	<0.001				

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 10

Rhythmometric Summary -- Diastolic Blood Pressure

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A +/- s.e.	(95% ci)	ACROPHASE (phi) +/- s.e	(95% ci)
			71.609 1.239						
1-H	1	24		23	<0.001	9.623 1.678	(6.33,12.91)	-233 11	(-212,-254)
		12		9	0.004	5.845 1.713	(2.49, 9.20)	-264 17	(-230,-298)
		overall		32	<0.001				
			72.487 1.247						
1-H	2	24		69	<0.001	24.266 1.687	(20.96,27.57)	-233 4	(-224,-241)
		12		5	<0.001	7.986 1.885	(4.29,11.68)	-292 12	(-268,-315)
		overall		74	<0.001				
			63.347 0.695						
2-N	1	24		48	<0.001	10.707 0.936	(8.87,12.54)	-256 5	(-245,-266)
		12		6	0.001	4.445 0.981	(2.52, 6.37)	-316 12	(-292,-340)
		overall		54	<0.001				
			65.704 0.730						
2-N	2	24		38	<0.001	9.016 1.018	(7.02,11.01)	-271 7	(-258,-284)
		12		4	0.003	3.427 0.966	(1.53, 5.32)	-2 18	(-328, -37)
		overall		42	<0.001				
			68.732 0.820						
3-H	1	24		54	<0.001	12.828 1.121	(10.63,15.03)	-206 5	(-196,-216)
		12		11	<0.001	5.865 1.119	(3.67, 8.06)	-319 12	(-296,-342)
		overall		65	<0.001				
			66.644 1.010						
3-H	2	24		35	<0.001	11.463 1.316	(8.88,14.04)	-216 8	(-202,-231)
		12		10	<0.001	6.293 1.432	(3.49, 9.10)	-299 13	(-275,-324)
		overall		45	<0.001				
			67.060 0.715						
4-N	1	24		45	<0.001	11.184 0.936	(9.35,13.02)	-221 6	(-210,-231)
		12		11	<0.001	5.905 1.027	(3.89, 7.92)	-248 10	(-230,-267)
		overall		57	<0.001				

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 10

Rhythmometric Summary -- Diastolic Blood Pressure (cont.)

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A +/- s.e.	(95% ci)	ACROPHASE (phi) +/- s.e	(95% ci)
			68.335 0.855						
4-N	2	24		30	<0.001	10.098 1.184	(7.78,12.42)	-245 7	(-231,-259)
		12		31	<0.001	10.140 1.249	(7.69,12.59)	-295 7	(-282,-308)
		overall		62	<0.001				
			66.689 1.073						
5-H	1	24		36	<0.001	10.820 1.536	(7.81,13.83)	-245 7	(-231,-260)
		12		3	0.360	1.977 1.349	(-0.67, 4.62)	-233 41	(-153,-314)
		overall		38	<0.001				
			59.197 0.721						
6-N	1	24		5	0.016	3.209 1.065	(1.12, 5.30)	-189 17	(-155,-224)
		12		12	0.001	4.113 1.012	(2.13, 6.10)	-284 14	(-256,-312)
		overall		17	0.001				
			59.153 1.004						
6-N	2	24		43	<0.001	10.869 1.387	(8.15,13.59)	-214 8	(-198,-229)
		12		4	0.007	4.625 1.397	(1.89, 7.36)	-269 18	(-233,-305)
		overall		46	<0.001				
			67.580 1.034						
7-H	1	24		16	0.001	6.303 1.394	(3.57, 9.04)	-242 14	(-215,-268)
		12		3	0.187	2.838 1.550	(-0.20, 5.88)	-258 27	(-205,-311)
		overall		18	0.002				
			61.770 0.783						
7-H	2	24		12	0.002	4.125 1.067	(2.03, 6.22)	-245 16	(-214,-276)
		12		6	0.039	2.915 1.137	(0.69, 5.14)	-282 21	(-241,-323)
		overall		18	0.001				
			66.156 1.035						
8-N	1	24		18	<0.001	8.916 1.461	(6.05,11.78)	-324 10	(-305,-343)
		12		34	<0.001	10.942 1.412	(8.17,13.71)	-285 8	(-270,-300)
		overall		52	<0.001				

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 10

Rhythmometric Summary -- Diastolic Blood Pressure (cont.)

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A	+/- s.e.	(95% ci)	ACROPHASE (phi)	+/- s.e	(95% ci)
			70.751 12.366								
8-N	2	24		21	0.166	5.757	7.013	(-7.99,19.50)	-166	169	(-195,-138)
		12		3	0.836	4.506	9.062	(-13.26,22.27)	-180	56	(-70,-290)
		overall		24	0.033						
			63.664 0.793								
9-H	1	24		57	<0.001	14.987	1.020	(12.99,16.99)	-241	5	(-232,-250)
		12		9	<0.001	4.707	1.097	(2.56, 6.86)	-85	13	(-59,-112)
		overall		67	<0.001						
			64.880 0.899								
9-H	2	24		47	<0.001	14.280	1.226	(11.88,16.68)	-257	5	(-246,-267)
		12		17	<0.001	9.048	1.237	(6.62,11.47)	-47	8	(-31, -63)
		overall		64	<0.001						
			62.076 0.987								
10-N	1	24		50	<0.001	14.710	1.379	(12.01,17.41)	-240	5	(-230,-251)
		12		5	<0.001	5.350	1.424	(2.56, 8.14)	-298	14	(-269,-326)
		overall		55	<0.001						
			63.416 1.011								
10-N	2	24		47	<0.001	11.740	1.404	(8.99,14.49)	-193	7	(-179,-207)
		12		6	0.002	4.815	1.456	(1.96, 7.67)	-253	17	(-220,-286)
		overall		53	<0.001						
			71.696 0.888								
11-H	1	24		3	0.001	5.398	1.021	(3.40, 7.40)	-241	15	(-212,-270)
		12		23	<0.001	7.378	1.181	(5.06, 9.69)	-290	9	(-273,-306)
		overall		26	<0.001						
			68.304 0.776								
11-H	2	24		8	<0.001	4.966	1.022	(2.96, 6.97)	-248	13	(-222,-274)
		12		31	<0.001	8.527	1.073	(6.42,10.63)	-330	7	(-316,-344)
		overall		39	<0.001						

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 10

Rhythmometric Summary -- Diastolic Blood Pressure (cont.)

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A +/- s.e.	(95% ci)	ACROPHASE (phi) +/- s.e	(95% ci)
			62.888 1.074						
12-N	1	24		31	<0.001	9.321 1.456	(6.47,12.18)	-236 10	(-217,-255)
		12		0	0.742	1.205 1.597	(-1.93, 4.34)	-256 67	(-125, -27)
		overall		31	<0.001				
			59.125 0.725						
12-N	2	24		18	<0.001	7.517 1.010	(5.54, 9.50)	-198 8	(-182,-214)
		12		30	<0.001	8.691 1.029	(6.67,10.71)	-305 7	(-292,-318)
		overall		49	<0.001				
			61.475 0.917						
13-H	1	24		23	<0.001	7.490 1.239	(5.06, 9.92)	-254 10	(-234,-274)
		12		0	0.546	1.388 1.328	(-1.22, 3.99)	-297 52	(-196, -39)
		overall		23	<0.001				
			62.056 0.993						
13-H	2	24		13	<0.001	6.359 1.557	(3.31, 9.41)	-189 12	(-166,-212)
		12		11	<0.001	5.955 1.275	(3.46, 8.45)	-326 15	(-297,-355)
		overall		24	<0.001				
			71.119 0.900						
14-N	1	24		37	<0.001	8.611 1.258	(6.14,11.08)	-254 9	(-237,-271)
		12		0	0.123	2.678 1.119	(0.48, 4.87)	-309 27	(-255, -2)
		overall		36	<0.001				
			74.006 1.207						
15-H	1	24		22	<0.001	8.778 1.689	(5.47,12.09)	-316 11	(-294,-338)
		12		13	<0.001	6.400 1.687	(3.09, 9.71)	-26 14	(-358, -54)
		overall		35	<0.001				
			73.461 1.135						
15-H	2	24		48	<0.001	12.673 1.513	(9.71,15.64)	-277 7	(-263,-292)
		12		5	0.015	4.356 1.689	(1.04, 7.67)	-329 19	(-291, -7)
		overall		53	<0.001				

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 10

Rhythmometric Summary -- Diastolic Blood Pressure (cont.)

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A +/- s.e.	(95% ci)	ACROPHASE (phi) +/- s.e	(95% ci)
			52.309 0.746						
16-N	1	24		11	0.004	3.424 1.075	(1.32, 5.53)	-294 17	(-260,-328)
		12		10	0.007	3.303 1.044	(1.26, 5.35)	-156 18	(-120,-192)
		overall		20	<0.001				
			63.159 1.786						
17-H	1	24		11	0.004	5.089 1.386	(2.37, 7.81)	-189 34	(-122,-257)
		12		14	0.002	5.755 1.749	(2.33, 9.18)	-263 20	(-222,-303)
		overall		25	0.002				
			68.998 0.998						
18-N	1	24		32	<0.001	8.169 1.459	(5.31,11.03)	-205 10	(-186,-224)
		12		6	0.057	3.216 1.329	(0.61, 5.82)	-194 26	(-143,-245)
		overall		38	<0.001				
			66.896 0.700						
19-H	1	24		38	<0.001	8.726 0.943	(6.88,10.57)	-225 7	(-211,-238)
		12		5	0.001	3.751 0.990	(1.81, 5.69)	-305 15	(-275,-334)
		overall		44	<0.001				
			64.737 0.707						
19-H	2	24		41	<0.001	7.954 0.987	(6.02, 9.89)	-234 7	(-220,-249)
		12		0	0.614	1.049 1.058	(-1.02, 3.12)	-272 52	(-170, -13)
		overall		41	<0.001				
			59.280 0.802						
20-N	1	24		4	0.001	4.492 1.172	(2.19, 6.79)	-183 14	(-156,-210)
		12		31	<0.001	8.040 1.096	(5.89,10.19)	-256 8	(-241,-271)
		overall		35	<0.001				
			73.187 1.037						
21-H	1	24		37	<0.001	14.038 1.545	(11.01,17.07)	-212 6	(-201,-223)
		12		37	<0.001	12.854 1.679	(9.56,16.15)	-332 6	(-321,-344)
		overall		74	<0.001				

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 10

Rhythmometric Summary -- Diastolic Blood Pressure (cont.)

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A +/- s.e.	(95% ci)	ACROPHASE (phi) +/- s.e	(95% ci)
			72.107 1.074						
21-H	2	24		59	<0.001	16.397 1.561	(13.34,19.46)	-299 5	(-289,-309)
		12		5	0.001	5.534 1.616	(2.37, 8.70)	-331 15	(-303,-360)
		overall		64	<0.001				
			64.130 0.946						
22-H	1	24		28	<0.001	9.173 1.191	(6.84,11.51)	-228 9	(-210,-246)
		12		15	<0.001	5.658 1.351	(3.01, 8.31)	-67 13	(-42, -49)
		overall		43	<0.001				
			74.902 0.907						
23-H	1	24		35	<0.001	6.947 1.184	(4.63, 9.27)	-243 11	(-221,-265)
		12		1	0.498	1.655 1.244	(-0.78, 4.09)	-307 47	(-216, -38)
		overall		37	<0.001				

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 11

Rhythmometric Summary -- Heart Rate

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A +/- s.e.	(95% ci)	ACROPHASE (phi) +/- s.e	(95% ci)
			68.276 1.181						
1-H	1	24		29	<0.001	10.876 1.703	(7.54,14.21)	-259 8	(-242,-276)
		12		11	0.001	6.467 1.600	(3.33, 9.60)	-289 15	(-259,-319)
		overall		40	<0.001				
			75.936 1.292						
1-H	2	24		55	<0.001	19.707 1.748	(16.28,23.13)	-233 6	(-222,-244)
		12		10	<0.001	9.358 1.914	(5.61,13.11)	-303 11	(-282,-325)
		overall		65	<0.001				
			78.398 0.859						
2-N	1	24		71	<0.001	21.487 1.233	(19.07,23.90)	-287 3	(-281,-294)
		12		6	<0.001	7.609 1.208	(5.24, 9.98)	-343 9	(-325, 0)
		overall		77	<0.001				
			75.746 0.794						
2-N	2	24		58	<0.001	14.859 1.112	(12.68,17.04)	-275 4	(-266,-283)
		12		3	<0.001	4.849 1.064	(2.67, 6.93)	-342 14	(-316, -9)
		overall		61	<0.001				
			72.294 0.929						
3-H	1	24		41	<0.001	10.648 1.353	(8.00,13.30)	-254 7	(-241,-268)
		12		1	0.459	1.571 1.301	(-0.98, 4.12)	-200 48	(-106,-294)
		overall		42	<0.001				
			78.078 1.110						
3-H	2	24		3	0.131	3.366 1.559	(0.31, 6.42)	-254 26	(-202,-306)
		12		26	<0.001	9.343 1.566	(6.27,12.41)	-247 9	(-229,-266)
		overall		29	<0.001				
			78.749 1.215						
4-N	1	24		19	<0.001	11.193 1.605	(8.05,14.34)	-233 9	(-214,-251)
		12		24	<0.001	11.190 1.754	(7.75,14.63)	-242 9	(-225,-258)
		overall		42	<0.001				

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 11

Rhythmometric Summary -- Heart Rate (cont.)

Subject		Period					AMPLITUDE			ACROPHASE		
#	Day	(hours)	Mesor +/- s.e	pr	p		A	+/- s.e.	(95% ci)	(phi)	+/- s.e	(95% ci)
			75.684	1.208								
4-N	2	24			42	<0.001	14.186	1.717	(10.82,17.55)	-270	7	(-257,-283)
		12			7	0.003	6.077	1.772	(2.60, 9.55)	-288	15	(-257,-318)
		overall			49	<0.001						
			66.690	1.431								
5-H	1	24			15	<0.001	7.630	1.646	(4.40,10.86)	-209	17	(-176,-241)
		12			6	0.025	4.951	1.764	(1.49, 8.41)	-254	22	(-210,-297)
		overall			21	<0.001						
			77.698	0.906								
6-N	1	24			8	<0.001	5.718	1.268	(3.23, 8.20)	-210	13	(-185,-236)
		12			24	<0.001	8.097	1.285	(5.58,10.61)	-274	9	(-257,-292)
		overall			32	<0.001						
			87.107	1.296								
6-N	2	24			56	<0.001	17.066	1.817	(13.50,20.63)	-207	6	(-194,-220)
		12			0	0.033	4.957	1.800	(1.43, 8.49)	-252	22	(-209,-296)
		overall			56	<0.001						
			73.504	0.736								
7-H	1	24			54	<0.001	11.129	0.971	(9.22,13.03)	-230	6	(-219,-241)
		12			2	0.022	3.127	1.107	(0.96, 5.30)	-269	17	(-235,-303)
		overall			56	<0.001						
			68.399	0.563								
7-H	2	24			49	<0.001	8.081	0.767	(6.58, 9.59)	-228	6	(-216,-239)
		12			6	0.002	2.965	0.819	(1.36, 4.57)	-274	15	(-245,-303)
		overall			54	<0.001						
			68.250	0.655								
8-N	1	24			33	<0.001	7.995	0.921	(6.19, 9.80)	-286	7	(-273,-299)
		12			30	<0.001	7.898	0.903	(6.13, 9.67)	-310	7	(-296,-323)
		overall			63	<0.001						

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 11

Rhythmometric Summary -- Heart Rate (cont.)

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A	+/- s.e.	(95% ci)	ACROPHASE (phi)	+/- s.e	(95% ci)
			81.957 10.278								
8-N	2	24		-3	0.159	7.698	13.835	(-19.42,34.82)	-121	48	(-26,-215)
		12		53	0.122	14.015	7.409	(-0.51,28.54)	-177	16	(-146,-208)
		overall		49	<0.001						
			66.733 0.997								
9-H	1	24		57	<0.001	17.654	1.286	(15.13,20.18)	-244	5	(-234,-253)
		12		4	0.053	3.421	1.373	(0.73, 6.11)	-62	23	(-16,-108)
		overall		62	<0.001						
			67.993 0.960								
9-H	2	24		50	<0.001	15.144	1.219	(12.76,17.53)	-230	6	(-219,-241)
		12		8	<0.001	6.800	1.336	(4.18, 9.42)	-59	11	(-37, -82)
		overall		58	<0.001						
			71.298 0.828								
10-N	1	24		29	<0.001	7.497	1.190	(5.16, 9.83)	-257	9	(-240,-274)
		12		1	<0.240	1.933	1.171	(-0.36, 4.23)	-325	34	(-258, -32)
		overall		30	<0.001						
			69.559 0.872								
10-N	2	24		48	<0.001	10.760	1.213	(8.38,13.14)	-227	7	(-213,-240)
		12		8	<0.001	5.409	1.151	(3.15, 7.67)	-281	14	(-254,-308)
		overall		56	<0.001						
			86.067 0.988								
11-H	1	24		8	0.004	5.073	1.188	(2.75, 7.40)	-246	17	(-212,-280)
		12		5	0.013	4.088	1.280	(1.58, 6.60)	-303	18	(-267,-339)
		overall		13	0.007						
			81.508 0.975								
11-H	2	24		16	<0.001	7.110	1.361	(4.44, 9.78)	-271	11	(-249,-293)
		12		11	<0.001	6.042	1.361	(3.37, 8.71)	-305	13	(-280,-329)
		overall		27	<0.001						

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 11

Rhythmometric Summary -- Heart Rate (cont.)

Subject #	Day	Period (hours)	Mesor +/- s.e		pr	p	AMPLITUDE A	+/- s.e.	(95% ci)	ACROPHASE (phi)	+/- s.e	(95% ci)
			89.232	0.832								
12-N	1	24			74	<0.001	17.233	1.204	(14.87,19.59)	-262	4	(-255,-270)
		12			0	0.773	0.866	1.241	(-1.57, 3.30)	-253	10	(-111, -34)
		overall			73	<0.001						
			78.727	0.800								
12-N	2	24			57	<0.001	14.858	1.080	(12.74,16.97)	-221	5	(-212,-230)
		12			10	<0.001	6.526	1.080	(4.41, 8.64)	-334	10	(-324, -5)
		overall			66	<0.001						
			84.771	1.063								
13-H	1	24			47	<0.001	14.755	1.438	(11.94,17.57)	-255	6	(-243,-266)
		12			1	0.371	2.182	1.446	(-0.65, 5.02)	-218	41	(-138,-298)
		overall			48	<0.001						
			89.420	1.148								
13-H	2	24			51	<0.001	16.260	1.821	(12.69,19.86)	-204	5	(-194,-215)
		12			6	<0.001	7.263	1.460	(4.40,10.13)	-343	14	(-315, -11)
		overall			57	<0.001						
			77.478	1.351								
14-N	1	24			46	<0.001	16.849	1.975	(12.98,20.72)	-230	6	(-218,-242)
		12			4	0.002	7.263	1.721	(3.81,10.56)	-297	15	(-268,-327)
		overall			50	<0.001						
			91.155	1.007								
15-H	1	24			43	<0.001	14.233	1.498	(11.29,17.16)	-350	5	(-340, -1)
		12			16	<0.001	7.977	1.460	(5.11,10.84)	-42	9	(-25, -60)
		overall			60	<0.001						
			87.900	0.748								
15-H	2	24			75	<0.001	16.097	1.078	(13.98,18.21)	-297	4	(-290,-304)
		12			6	<0.001	4.787	1.070	(2.69, 6.88)	-350	12	(-326, -14)
		overall			82	<0.001						

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 11

Rhythmometric Summary -- Heart Rate (cont.)

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A +/- s.e.	(95% ci)	ACROPHASE (phi) +/- s.e	(95% ci)
			64.771 0.711						
16-N	1	24		75	<0.001	15.843 0.975	(13.93,17.75)	-275 4	(-267,-282)
		12		1	0.108	2.158 1.028	(0.14, 4.17)	-280 26	(-229,-330)
		overall		75	<0.001				
			60.537 1.792						
17-H	1	24		14	0.001	8.357 2.044	(4.35,12.36)	-224 18	(-188,-260)
		12		12	0.002	7.365 1.493	(4.44,10.29)	-303 18	(-269,-337)
		overall		26	0.001				
			70.545 0.667						
18-N	1	24		66	<0.001	10.880 0.978	(8.96,12.80)	-205 5	(-195,-214)
		12		0	0.238	1.500 0.875	(-0.21, 3.21)	-348 38	(-274, -62)
		overall		66	<0.001				
			63.630 0.689						
19-H	1	24		26	<0.001	6.719 0.977	(4.80, 8.63)	-252 8	(-236,-269)
		12		13	<0.001	4.647 0.981	(2.73, 6.57)	-336 12	(-312,-359)
		overall		40	<0.001				
			62.902 0.513						
19-H	2	24		25	<0.001	4.409 0.748	(2.94, 5.88)	-265 9	(-247,-283)
		12		14	<0.001	3.388 0.748	(1.92, 4.85)	-292 12	(-269,-316)
		overall		39	<0.001				
			73.103 0.946						
20-N	1	24		13	<0.001	5.762 1.131	(3.55, 7.98)	-241 15	(-212,-270)
		12		2	<0.107	2.786 1.315	(0.21, 5.36)	-272 26	(-222,-322)
		overall		15	<0.001				
			68.298 1.523						
21-H	1	24		48	<0.001	16.918 2.262	(12.48,21.35)	-217 7	(-203,-231)
		12		6	0.012	6.143 2.464	(1.31,10.97)	-333 19	(-296, -9)
		overall		54	<0.001				

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

Table 11

Rhythmometric Summary -- Heart Rate (cont.)

Subject #	Day	Period (hours)	Mesor +/- s.e	pr	p	AMPLITUDE A +/- s.e. (95% ci)	ACROPHASE (phi) +/- s.e (95% ci)
			78.074 0.900				
21-H	2	24		66	<0.001	16.162 1.315 (13.59,18.74)	-303 4 (-294,-311)
		12		7	0.004	4.653 1.178 (2.34, 6.96)	-58 17 (-25, -91)
		overall		74	<0.001		
			64.409 0.605				
22-H	1	24		56	<0.001	11.404 0.895 (9.65,13.16)	-275 4 (-267,-283)
		12		11	<0.001	4.961 0.827 (3.34, 6.58)	-25 10 (-6, -43)
		overall		68	<0.001		
			82.888 0.935				
23-H	1	24		71	<0.001	15.416 1.182 (13.10,17.73)	-253 5 (-243,-263)
		12		3	0.025	4.097 1.427 (1.30, 6.89)	-278 17 (-244,-312)
		overall		74	<0.001		

Note. s.e. = standard error; pr = percent rhythm; H = Hypertensive; N = Normotensive; ci= confidence interval

for age, sex, and ethnicity. One-hour averages were determined to minimize correlation within the data. Except for Pair 3/4, the mesor systolic blood pressure was significantly lower ($p < .010$ to .001) in the normotensive than in the hypertensive students. A matched pairs one-tailed t-test of first profile and when possible, second profile systolic blood pressure mesor data also revealed a significant difference in this parameter ($p = .0005$, $df = 13$).

Although Pairs 3/4, 7/8, and 9/10 did not demonstrate statistically significant differences in mesor diastolic blood pressure, the normotensive adolescent demonstrated significantly lower mesor diastolic blood pressure values ($p < .001$)than their hypertensive counterparts for Pairs 1/2, 5/6, 11/12, 15/16, and 19/20. In contrast, Pairs 13/14 and 17/18 reflected significantly higher mesor diastolic blood pressure measurements ($p = .001$ and .008 respectively). In these cases, the normotensive individual had the higher mesor diastolic blood pressure value.

The population mean cosinor values and the corresponding parameter tests between hypertensive and normotensive adolescents for systolic and diastolic blood pressures are presented in Tables 13 through 15. These cosinor values were calculated by pooling the data from each subject when two profiles were available, irrespective of

whether data was collected on consecutive or nonconsecutive days. The p levels of less than .001 to .036 again indicate a remote possibility that the mean cosinor values varied by chance. For both 24-hour periods, mesor systolic blood pressure (see Table 13) demonstrated significant differences between the two groups ($F = 32.40825$, $df = 1/36$, $p = .0001$ and $F = 18.48606$, $df = 1/21$, $p = .0003$). Significant differences between mesor diastolic blood pressure (see Table 14) were observed only for the second 24-hour period ($F = 4.30657$, $df = 1/21$, $p = .0504$).

Hypothesis 2 stated: There are no significant differences in heart rate mesors between normotensive and hypertensive adolescents. Although the findings are mixed, they suggest support for this null hypothesis. As displayed in Table 12, the normotensive student had significantly lower heart rate mesors ($p \leq .001$) for Pairs 13/14, 15/16, and 19/20. Conversely, the normotensive subject had significantly higher heart rate mesors in Pairs 1/2, 5/6, and 17/18 ($p = .026$, $< .001$, and $< .001$ respectively). The remaining four hypertensive/normotensive student pairs reflected no statistically significant differences in heart rate mesor.

The corresponding parameter tests for heart rate mesor (see Table 15) noted a significant difference in this parameter between the normotensive and hypertensive

adolescent only for the second 24-hour period (F = 8.53479, df = 1/36, p = .0060).

Hypothesis 3 stated: There are no significant differences in systolic/diastolic blood pressure amplitudes between normotensive and hypertensive adolescents. While the results are again mixed, they tend to not support the null hypothesis. Three of the ten student pairs revealed the normotensive subject to have significantly lower systolic (Pairs 9/10, 15/16, and 19/20) and diastolic (Pairs 1/2, 5/6, and 15/16) blood pressure amplitudes (p = .003 to .045). The corresponding parameter tests for systolic blood pressure amplitude demonstrated a significant difference between the two student groups for the second 24-hour period (see Table 13, F = 4.69178, df = 1/21, p = .0420). The matched pairs one-tailed t-test of first profile and when possible, second profile systolic blood pressure amplitude data revealed a significant difference in this parameter (p = .023, df = 13).

Hypothesis 4 stated: There are no significant differences in heart rate amplitudes between normotensive and hypertensive adolescents. This null hypothesis was supported as only three of ten heart rate amplitudes reflected significant differences in this parameter between the two groups [Pair 9/10 (p = .002), Pair 10/11 (p = .003), and Pair 17/18 (p = .021)]. Furthermore, in Pairs 11/12 and

17/18, the normotensive subject had the greater amplitude. Additional information to support the null hypothesis was provided by the heart rate amplitude equality test (see Table 15) as no significant difference in this parameter was generated by the matched pairs for either period (F = .20413, df = 1/21, p = .6560 and F = 1.56930, df = 1/36, p = .2183).

Hypothesis 5 stated: As reflected by acrophase and mean percent rhythm, there are no significant differences in circadian rhythm synchrony between normotensive and hypertensive adolescents. It is discussed within the context of the following three null hypotheses.

Hypothesis 5a stated: There are no significant differences in systolic/diastolic blood pressure acrophases between normotensive and hypertensive adolescents. This null hypothesis was supported for only three of the ten pairs (see Table 12) had significant differences for both systolic and diastolic blood pressures (Pairs 1/2, 5/6, and 9/10). For these parameters, there were significant phase delays in their rhythms' peaks (Pair 5/6, p = .019 and .012 for systolic and diastolic blood pressure respectively; pair 9/10, p = .023 and .026 for systolic and diastolic blood pressure respectively). In other words, the peaks demonstrated a positive shift or occurred earlier in the day for the normotensive student. Conversely, the normotensive

Table 12

Matched Pair Comparison -- p Values for Combined Data (Hourly Averages)

Subject Comparison	Systolic Blood Pressure			Diastolic Blood Pressure			Heart Rate		
	M	A	ϕ	M	A	ϕ	M	A	ϕ
1/2	<.001↓	.114	.014→	<.001↓	.008↓	.018→	.026↑	.291	.002→
3/4	.968	.770	.272	.717	.386	.128	.808	.206	.822
5/6	<.001↓	.437	.019←	<.001↓	.006↓	.023←	<.001↑	.575	.882
7/8	.002↓	.198	.034	.728	.312	.381	.053	.200	.056
9/10	<.001↓	.048↓	.012←	.423	.491	.026←	.076	.002↓	.442
11/12	<.001↓	.675	.133	<.001↓	.534	.241	.702	.003↑	.355
13/14	<.001↓	.516	.902	<.001↑	.307	.682	<.001↓	.443	.151
15/16	<.001↓	.007↓	.821	<.001↓	.003↓	.670	<.001↓	.246	<.001←
17/18	.010↓	.255	.150	.008↑	.138	.628	<.001↑	.021↑	.901
19/20	<.001↓	.019↓	.881	.001↓	.055	.365	<.001↓	.758	.727

Note. M = mesor; A = amplitude; ϕ = acrophase; ↓ = lower or ↑ = higher in the normotensive subject; → = phase-advanced or ← = phase-delayed in the normotensive subject. The odd numbers represent the hypertensive subjects while the even numbers indicate their matched normotensive counterparts.

Table 13

Comparison of Systolic Blood Pressure Population - Mean Cosinor Values between Hypertensive and Normotensive Adolescents

Population	k	mesor +/- ci		amplitude +/- ci		acrophase	(95% ci)	p-value
Hypertensive	22	122.531	2.166	8.376	1.865	-251	(- 41,- 60)	< 0.001
Normotensive	16	112.683	3.061	5.613	2.409	-242	(-225,-261)	0.001
combined parameters		118.385		7.193		-248		

tests of equality of parameters

parameter(s)	df	f	p
mesor	(1,36)	32.40825	< 0.0001
amplitude	(1,36)	3.80958	0.0588
acrophase	(1,36)	0.88719	0.3525
(a, phi)	(2,70)	2.31247	0.1065

Note. 0.05 is the selected probability level; k = number of cases; df = degrees of freedom; ci = confidence interval. Data reflects the first 24-hour period.

Table 13

Comparison of Systolic Blood Pressure Population - Mean Cosinor Values between Hypertensive and Normotensive Adolescents (cont.)

Population	k	mesor	+/- ci	amplitude	+/- ci	acrophase	95%ci	p-value
Hypertensive	13	122.416	2.787	8.231	2.443	-252	(-240,-262)	< 0.001
Normotensive	10	113.035	4.202	4.523	3.009	-240	(-213,-270)	0.036
combined parameters		118.337		6.589		-248		

tests of equality of parameters·

parameter(s)	df	f	p
mesor	(1,21)	18.48606	0.0003
amplitude	(1,21)	4.69178	0.0420
acrophase	(1,21)	1.02363	0.3232
(a, phi)	(2,40)	2.60233	0.0866

Note. 0.05 is the selected probability level; k = number of cases; df = degrees of freedom; ci = confidence interval. Data reflects the second 24-hour period.

Table 14

Comparison of Diastolic Blood Pressure Population - Mean Cosinor Values between Hypertensive and Normotensive Adolescents

Population	k	mesor	+/- ci	amplitude	+/- ci	acrophase	(95% ci)	p-value
Hypertensive	22	74.697	4.085	9.241	2.254	-253	(-229,-257)	< 0.001
Normotensive	16	75.165	3.805	11.060	2.609	-250	(-216,-253)	< 0.001
combined parameters		74.894		10.004		-251		

tests of equality of parameters

parameter(s)	df	f	p
mesor	(1,36)	0.02859	0.8667
amplitude	(1,36)	1.19665	0.2813
acrophase	(1,36)	0.06379	0.8020
(a, phi)	(2,70)	0.59670	0.5534

Note. 0.05 is the selected probability level; k = number of cases; df = degrees of freedom; ci = confidence interval. Data reflects the first 24-hour period.

Table 14

Comparison of Diastolic Blood Pressure Population - Mean Cosinor Values between Hypertensive and Normotensive Adolescents (cont.)

Population	k	mesor	+/- ci	amplitude	+/- ci	acrophase	(95% ci)	p-value
Hypertensive	13	67.733	2.645	8.355	2.472	-243	(-228,-258)	< 0.001
Normotensive	10	63.495	3.887	5.634	2.729	-233	(-211,-258)	0.007
combined parameters		65.891		7.148		-239		

tests of equality of parameters

parameter(s)	df	f	p
mesor	(1,21)	4.30657	0.0504
amplitude	(1,21)	2.67626	0.1168
acrophase	(1,21)	0.60303	0.4461
(a, phi)	(2,40)	1.65740	0.2035

Note. 0.05 is the selected probability level; k = number of cases; df = degrees of freedom; ci = confidence interval. Data reflects the second 24-hour period.

Table 15

Comparison of Heart Rate Population - Mean Cosinor Values between Hypertensive and Normotensive Adolescents

Population	k	mesor	+/- ci	amplitude	+/- ci	acrophase	(95% ci)	p-value
Hypertensive	13	73.764	5.391	9.215	2.807	-253	(-237,-272)	< 0.001
Normotensive	10	74.462	4.169	10.025	2.516	-247	(-222,-268)	< 0.001
combined parameter		74.067		9.551		-250		

tests of equality of parameters

parameter(s)	df	f	p
mesor	(1,21)	0.04593	0.8324
amplitude	(1,21)	0.20413	0.6560
acrophase	(1,21)	0.27486	0.6056
(a, phi)	(2,40)	0.23501	0.7916

Note. 0.05 is the selected probability level; k = number of cases; df = degrees of freedom; ci = confidence interval. Data reflects the second 24-hour period.

Table 15

Comparison of Heart Rate Populations - Mean Cosinor Values between Hypertensive and Normotensive Adolescents (cont.)

Population	k	mesor	+/- ci	amplitude	+/- ci	acrophase	(95% ci)	p-value
Hypertensive	22	67.991	2.005	8.437	2.173	-242	(-237,-271)	< 0.001
Normotensive	16	63.608	2.460	6.513	2.295	-234	(-231,-266)	< 0.001
combined parameters		66.146		7.608		-239		

tests of equality of parameters

parameter(s)	df	f	p
mesor	(1,36)	8.53479	0.0060
amplitude	(1,36)	1.56980	0.2183
acrophase	(1,36)	0.55135	0.4626
(a, phi)	(2,70)	1.23299	0.2977

Note. 0.05 is the selected probability level; k = number of cases; df = degrees of freedom; ci = confidence interval. Data reflects the first 24-hour period.

individual for Pair 1/2 displayed a negative shift (p = .014and .018 for systolic and diastolic blood pressure respectively). This phase advancement means that the rhythm peaked later in the day. Tests of equality (see Tables 13 and 14) also indicated no significant acrophase differences between the hypertensive/normotensive adolescents for any 24-hour period(F = .88719, df = 1/36, p =.3525 and F = 1.02363, df = 1/21, p = .3232 for systolic blood pressure; F = .06379, df = 1/36, p = .8020 and F = .60303, df = 1/21, p = .4461 for diastolic blood pressure).

Hypothesis 5b stated: There are no significant differences in heart rate acrophases between normotensive and hypertensive adolescents. Because only Pairs 1/2 and 15/16 reflected any statistically significant differences in heart rate acrophase between the two groups (p = .002 and < .001 respectively), the null hypothesis was supported (see Table 12). Even these two results were conflicting. The normotensive subject in Pair 1/2 demonstrated phase-advancement while in Pair 15/16, a phase delay was observed. Tests of equality (see Table 15) also indicated no significant heart rate acrophase differences between the hypertensive/normotensive adolescents for any 24-hour period (F = .27486, df = 1/21, p = .6056 and F = .55135, df = 1/36, p = .4626).

Hypothesis 5c stated: There are no significant

differences in mean percent rhythms between normotensive and hypertensive adolescents. The mean percent rhythm for the normotensive group was 36.8 as compared to 36.6 for the hypertensive group. A lower percent rhythm indicates the variable to be more loosely coupled to its driving oscillator. However, a one-tailed *t*-test for independent samples determined that this null hypothesis should be supported because the observed *t*-value (.944) was not greater than the critical *t*-value (*t* = 1.771, *df* = 13, and *p* = .05).

Hypothesis 6 stated: There are no significant differences in overall circadian hyperbaric indices (HBI) between normotensive and hypertensive adolescents. This null hypothesis was not supported but with reservation because of the small sample size. In the second profile, hypertensive Subject 1 demonstrated a diastolic blood pressure excess of 31 mm Hg x h. Two profiles of hypertensive Subject 21 were each 7 mm Hg x h (again, for diastolic blood pressure excess). However, there was no significant excess for either systolic blood pressure or heart rate. For Subject 15, there was a systolic blood pressure excess of 13 and 10 mm Hg x h in the two profiles.

Summary of Findings

The findings are summarized to respond to the research problem statement and subquestions. The problem statement

is "What are the similarities and/or differences in blood pressure and heart rate circadian rhythmic patterns between normotensive and hypertensive adolescents?"

The first subquestion asked: "What are the similarities and/or differences in blood pressure and heart rate level (mean or mesor), amplitude, and acrophase between normotensive and hypertensive adolescents?" Except for one normotensive/hypertensive student pair, the mesor systolic blood pressure was significantly lower ($p \leq .010$ to .001) in the normotensive adolescent. A matched pairs one-tailed t-test also revealed a significant difference in this parameter between the two groups ($p = .0005$, $df = 13$) as did the equality parameter tests for both periods ($F = 32.40825$, $df = 1/36$, $p = .0001$ and $F = 18.48606$, $df = 1/21$, $p = .0003$).

Concerning amplitude, a matched pairs one-tailed t-test revealed a significant difference only in systolic blood pressure amplitude between the normotensive / hypertensive adolescents ($p = .023$, $df = 13$). The corresponding parameter tests also demonstrated a significant difference in this parameter but only for the second 24-hour period ($F = 4.69178$, $df = 1/21$, $p = .0420$).

Because heart rate and systolic/diastolic blood pressure acrophases and diastolic blood pressure and heart rate mesors revealed mixed differences, the null hypotheses

concerning these parameters were not supported.

The second subquestion asked: "What are the similarities and/or differences in blood pressure and heart rate circadian rhythmic coordination between normotensive and hypertensive adolescents?" Acrophase, the peak or highest point of a complete recurrent cycle, provides a perspective of circadian rhythmic coordination. The matched pair comparison -- p values for combined data (hourly averages) indicated that even when parameters were either significantly phase advanced or phase delayed, there was consistency or coordination in this direction.

Subject Comparison	Acrophase SBP	DBP	HR
1/2	.014→	.018→	.002→
5/6	.019←	.023←	---
9/10	.012←	.026←	.001←

Note. SBP = systolic blood pressure; DBP = diastolic blood pressure; HR = heart rate; → phase advanced or ← phase delayed in the normotensive subject. The odd numbers represent the hypertensive subjects while the even numbers indicate their matched normotensive counterparts.

The third subquestion asked: "Is there a relationship between circadian rhythm synchrony and blood pressure level?" A one-tailed t-test for independent samples determined that because the observed t-value (.944) was not greater than the critical t-value ($t = 1.771$, $df = 13$, and $p = .05$), there was no significant difference in synchrony as reflected by mean percent rhythm between the two adolescent

samples. The mean percent rhythm for the normotensive group was 36.8 as compared to 36.6 for the hypertensive group.

The fourth subquestion asked: "What is the distribution of the circadian overall hyperbaric index (HBI)?" Because three hypertensive subjects demonstrated significant parameter excesses, the null hypothesis that there are no significant differences in HBI between normotensive and hypertensive adolescents was not supported. This conclusion was made with reservation because of the small sample size. The findings, however, do suggest that further research is warranted.

The fifth subquestion asked: "How do the blood pressure measurements obtained by the recently developed SpaceLabs 90202 unit compare with those obtained via auscultation or direct arterial monitoring?"

Validation Study

Two physicians, a research nurse, and the investigator conducted a study to determine the validity and reliability of the Space Labs 90202 Monitor in a: (a) children's intensive care unit; (b) cardiac catheterization lab; and (c) cardiology clinic. Measures of central tendency and variability did reveal differences in simultaneous blood pressure readings among direct arterial, oscillometric, and auscultatory methods. However, the standard deviations for all measurement techniques were within normal limits (see

Table 4, p. 70). Most pertinent to the cardiovascular circadian rhythm study, frequency histograms (see Table 5, p. 84) revealed that auscultatory blood pressure measurements compared quite highly with those obtained by the SpaceLabs unit. For systolic blood pressure, 125 of 129 measurements (96.9%) were within ± 15 mm Hg of each other. Correlation equaled 0.97. For diastolic blood pressure, 123 of 134 readings (91.8%) were within ± 10 mm Hg of each other. Correlation was 0.91. The paired *t*-test for dependent samples (see Table 6, p. 85) revealed no significant differences in blood pressure readings when the SpaceLabs unit's measurements were compared with either auscultatory (p = .001 and .05 for systolic and diastolic blood pressures respectively) or direct arterial measurements (p = .001 and .02 for systolic and diastolic blood pressures respectively).

Cardiovascular Circadian Rhythm Study

The Wilcoxon matched pairs-signed ranks test analyzed differences between heart rate and blood pressure measurements when the SpaceLabs 90202 monitor was connected to and disconnected from each adolescent subject (see Table 3, p. 62). Only a small yet significant difference existed between the heart rate measurements obtained by the blood pressure units and those palpated by the investigator. In other words, the null hypothesis was not supported because

the heart rate critical and observed p values were equal (.0164). The discrepancy was attributed to: (a) investigator and/or unit measurement error; (b) comparing heart rate obtained via oscillometric technique with that palpated for thirty seconds then multiplied by two; and (c) the time lapse of one to two minutes between unit and palpation measurements.

CHAPTER V

SUMMARY OF THE STUDY

A summary of the study and a discussion of findings as compared to other research are presented. Conclusions and implications based upon these findings are followed by recommendations for further study as related to nursing research, practice and education.

Summary

This quantitative-descriptive, hypothesis testing field study was designed to quantify the similarities and/or differences in blood pressure and heart rate circadian rhythmic patterns between normotensive and hypertensive adolescents. The purposes of the investigation were:

1. To quantify adolescent blood pressure/heart rate diversity, complexity, and frequency as reflected in circadian rhythmic patterning and repatterning.

2. To establish a scientific basis for continued nursing research and theory development in circadian rhythmic patterns.

3. To validate the SpaceLabs 90202 Ambulatory Blood Pressure Monitor.

Chronobiology and Rogers' resonancy, helicy, and integrality principles dovetailed to form the theoretical framework for this study. Chronobiology, of which circadian (24-hour) rhythmicity is a component, is an emerging science

offering a unique rhythmometric perspective of life. Rhythms with different frequencies are found at all levels of biologic integration... (Halberg et al., 1972). In the case of human blood pressure, relatively dense measurement series have served to derive indices of these rhythms that can be readily computed, intuitively compared, and validated by inferential statistics (Halberg et al., 1984). Although these patterns are peculiar to each individual, there are similarities among subjects compared by age, sex, and living conditions.

Within Rogers' (1983) theoretical framework, man and environment are defined as four-dimensional, negentropic energy fields identified by pattern and organization. Pattern and organization identify a human being and reflect innovative wholeness. Pattern recognition as a means of distinguishing individuals is an everyday occurrence.

> Patterning is a dynamic process.... Man's capacity to maintain himself while undergoing continuous change is a remarkable characteristic. This capacity is commonly referred to as man's self-regulating ability.... Efforts to identify self-regulatory mechanisms operating in man have revealed a range of physiological functioning (Rogers, 1983, pp. 62-63).

Self-regulation is identified with maintaining multiple functions in living systems and directed toward: (a) achieving increasing complexity of organization; and (b) fulfilling the potentialities of life (Rogers, 1983).

This Rogerian perspective again complements chronobiology which postulates that a multioscillator system (biological clock) promotes temporal order within the organism, keeping diverse rhythms in distinct phase relationships with one another as daily changes occur (Aschoff et al., 1967; Moore-Ede et al., 1976). These rhythmic cycles are prompted by external cues which help man maintain normal or near normal functioning patterns. Man's health is optimal when his circadian rhythms are synchronized with his life style and life cycle (Aschoff, 1965). While the multiple oscillators are usually coupled to one another, their cycles or phase relationships can become dysynchronous under certain conditions.

With the advent of and improvement in automatic instruments for obtaining blood pressure and heart rate measurements, the ability to identify circadian rhythmic patterns in normotensive and hypertensive young people is now greatly enhanced. Understanding blood pressure fluctuations is fundamental in developing a dynamic nursing knowledge base for regulatory decision-making in prevention and health promotion. There is little information regarding if, and to what extent, elevated blood pressure levels alter and reorganize blood pressure and heart rate circadian rhythmic patterns in this population. It is anticipated that these alterations could occur and are more

dysynchronous in the hypertensive adolescent.

These findings would have nursing implications as they would shed some understanding of circadian variations and the complex, multiple factors modulating blood pressure. This understanding of an individual's early natural history is a prerequisite for primary prevention and intervention with the ultimate goal to be the directing and redirecting of patterns of the human and environmental fields for realization of maximum health potential.

Adolescents identified as having high blood pressure levels (greater than the age-sex specific 90th percentile values of blood pressure for sex) and normotensive students with a family history of hypertension were screened on three separate occasions by the investigator and/or four high school student research assistants trained by the investigator. Twenty-seven students were determined to have high blood pressure. Twenty met the following delimitations:

1. day-active people.
2. 13 to 19 years old (inclusive).
3. enrolled in a metropolitan health magnet high school.
4. able to read and comprehend English.
5. if hypertensive, primary type hypertension only.
6. dysrhythmia-free.

7. not pregnant or taking birth control pills.

8. if normotensive, no family history of hypertension.

9. no history of diabetes or other hormonal problems, renal disease, or cardiac disease (including aortic incompetence and coarctation of the aorta). Thirteen hypertensive individuals agreed to participate in the study.

Because of the possible confounding effects of blood pressure medication, other health problems, etc., each hypertensive student was individually assessed for sample inclusion by the investigator and a pediatric cardiologist nationally recognized for his expertise in the area of adolescent hypertension. A stratified random normotensive group without a family hypertensive history was matched with ten hypertensive students for age, sex, and ethnicity.

After all necessary consents and demographic information were obtained, each student wore the SpaceLabs 90202 Ambulatory Blood Pressure Monitor for 24 to 48 hours programmed to inflate the blood pressure cuff every 10 to 20 minutes. An Activity Diary facilitated data interpretation.

Rhythmometric analysis (Halberg, 1969) calculated the best unbiased estimates of population parameters such as mesors (means), amplitudes (magnitude of variation), acrophases (peaks), and mean percent rhythm for heart rate and systolic/diastolic blood pressures. It identified: (a) synchrony or dysynchrony among the rhythms; and (b) the

overall circadian hyperbaric index (HBI). Equality parameter tests and t-tests for dependent samples were also employed to answer the following null hypotheses:

1. There are no significant differences in systolic / diastolic blood pressure mesors between normotensive and hypertensive adolescents. This hypothesis was not supported as significantly higher systolic blood pressure mesors were observed in the hypertensive adolescent group.

2. There are no significant differences in heart rate mesors between normotensive and hypertensive adolescents. Although the findings were mixed, they suggested support for this null hypothesis.

3. There are no significant differences in systolic / diastolic blood pressure amplitudes between normotensive and hypertensive adolescents. Although the cosinor analysis generated mixed results, the equality parameter t-tests recommended that this null hypothesis not be supported. The parameter test for systolic blood pressure amplitude demonstrated a significant difference between the two groups for the second 24-hour period. The matched pairs one-tailed t-test for this same parameter also revealed a significant difference between the hypertensive and normotensive students.

4. There are no significant differences in heart rate amplitudes between normotensive and hypertensive

adolescents. This null hypothesis was supported as the statistical tests revealed no significant differences in this parameter between the two groups.

5. As reflected by acrophase and mean percent rhythm, there are no significant differences in circadian rhythm synchrony between normotensive and hypertensive adolescents. It was discussed within the context of the following three null hypotheses:

5a. There are no significant differences in systolic/diastolic blood pressure acrophases between normotensive and hypertensive adolescents. Because the two groups compared similarly, the null hypothesis was supported.

5b. There are no significant differences in heart rate acrophases between normotensive and hypertensive adolescents. Because only two of the ten normotensive / hypertensive student pairs reflected any statistically significant differences, this null hypothesis was supported. Even these two results were conflicting as one pair demonstrated phase advancement while in the other pair, a phase delay was observed.

5c. There are no significant differences in mean percent rhythms between normotensive and hypertensive adolescents. A one-tailed t-test for independent samples determined that this null hypothesis should be supported because the observed t-value was greater than the critical

t-value.

6. There are no significant differences in overall circadian hyperbaric indices between normotensive and hypertensive adolescents. The null hypothesis was not supported but with reservation because: (a) of the small sample size; and (b) only three of thirteen hypertensive students demonstrated any parameter excesses.

The dissertation research also sought to establish the validity and reliability of the SpaceLabs unit employed to monitor and record systolic / diastolic blood pressure and heart rate. Therefore, a research subquestion asked: "How do the pressure measurements obtained by the recently developed SpaceLabs device compare with those obtained by auscultation or direct arterial monitoring?"

The SpaceLabs Validation Study was conducted concurrently with the adolescent cardiovascular circadian rhythm research. Two physicians, a research nurse, and the investigator sought to determine the unit's validity and reliability in three settings: (a) a children's intensive care unit; (b) a cardiac catheterization lab; and (c) a cardiology clinic. Most pertinent to the cardiovascular circadian rhythm study, frequency histograms revealed that auscultatory blood pressure measurements compared quite highly with those obtained by the SpaceLabs unit. The paired t-test for dependent samples revealed no significant

differences in blood pressure readings when the SpaceLabs monitor's measurements were compared with either auscultatory or direct arterial measurements.

The Wilcoxon matched pairs-signed ranks test analyzed differences between heart rate and blood pressure measurements when the SpaceLabs device was connected to and disconnected from each adolescent subject. Only a small yet significant difference existed between the heart rate measurements obtained by the blood pressure units and those palpated by the investigator. In other words, the null hypothesis was not supported because the heart rate critical and observed *t*-values were equal. The discrepancy was attributed to: (a) investigator and/or measurement error; (b) comparing heart rate obtained via oscillometric technique with that palpated for thirty seconds then multiplied by two; and (c) the time lapse of one to two minutes between unit and palpation measurements.

Discussion of Findings

Findings from both adolescent cardiovascular circadian rhythm studies and the SpaceLabs validation will be compared to other research. Data from research studying adolescent hypertension is currently being pooled in order to establish a cardiovascular circadian rhythm data base for this population (F. Halberg, personal communication, March, 1986; C. Ferencz, personal communication, September, 1987).

Although only three of the thirteen hypertensive students demonstrated significant parameter excesses, it does concur with Halberg et al. (1984) that further research in this area is warranted. Additional impetus is provided when it is remembered that two of these three subjects had diastolic blood pressure excesses in the second profile. The ambulatory blood pressure monitor's novelty effect should have been minimal during the second 24-hour period. Also, diastolic pressure fluctuates to a lesser extent than does systolic blood pressure (Drayer et al., 1985).

Investigations in other populations also provide impetus for continued study. Blood pressure and heart rate circadian rhythm differences were observed in hypertensive and normotensive men and women (Millar-Craig, Bishop, and Raftery, 1978). Normotensive subjects demonstrated an increase in heart rate before awakening yet no blood pressure peak at 1000 when compared to the hypertensive individuals.

Blood pressure circadian rhythmicity in 9 and 10 year old Italian school children identified significant differences in blood pressure mesor, amplitude and acrophase as related to a family history of hypertension (Scarpelli et al., 1985). This correlation between significant fluctuations in circadian rhythmicity and a hypertensive family history was also suggested when neonates

with larger circadian amplitudes were discovered to have such a family health history (Halberg et al, 1986).

It was determined that the SpaceLabs 90202 Ambulatory Blood Pressure Monitor was a valid instrument for recording cardiovascular parameters in children and adolescents. Results from numerous ongoing nationwide studies may confirm the findings cited in Chapter III as well as suggest areas for future research. The two studies employing the SpaceLabs 5200 device were conducted in the adult population (Dembroski & MacDougall, 1985; Pagny et al., 1987). While the SpaceLabs 5200 unit demonstrated lower mean blood pressure measurements when compared to the auscultatory technique, the converse was demonstrated with the newer model in children. Pagny et el. (1987) agreed with the smaller standard deviations reflected by the oscillometric device. However, Dembroski and MacDougall (1985) did not find this to be true.

Frequency analysis revealed greater variation in the blood pressure measurements recorded by the SpaceLabs 90202 than those monitored by the SpaceLabs predecessor (Dembroski & MacDougall, 1985). In both studies, however, scatterplots illustrated a high degree of linearity for oscillometric and auscultatory comparisons. Systolic and diastolic blood pressures correlations equaled 0.86 and 0.85 respectively (Dembroski & MacDougall, 1985). The dissertation research

validation study demonstrated even higher correlations (systolic and diastolic blood pressures = .97 and .91 respectively).

In the cardiology clinic, pre- and post-exercise periods were selected for SpaceLabs 90202 recording because of frequent error codes being generated under exercise conditions. It's important that this limitation be minimized as exercise induced hypertension in adolescents may be a predictive marker of early adult essential hypertension (Garrett et al., 1985).

Conclusions and Implications

Because the mesor systolic blood pressure was significantly lower ($p \leq .010$ to .001) in the normotensive adolescent, the National Heart, Lung, and Blood Institute's Task Force recommendations (1986) for age/sex-specific 90th to 95th blood pressure percentiles are valid parameters by which to indicate those adolescents with high versus normal blood pressure levels. Weight has been shown to be positively correlated with systolic blood pressure (Lauer, Burns, & Clarke, 1985; Voors, Webber, & Berensen, 1978). In this study, five hypertensive students were greater than their age/sex-specific 90th percentile weight values. However, none of these five students were taller than their corresponding age/sex-specific 90th percentile height measurements.

The Task Force has also suggested that "high blood pressure levels" replace the term "hypertension". This study supports this contention as all subjects had a certain percentage of elevated pressures (see Figures 15 & 16). In Figure 15, Subject 18 (classified as normotensive by the blood pressure screening program) recorded a greater number of high blood pressure levels than did his "hypertensive" counterpart. Figure 16 illustrates higher diastolic blood pressure measurements for "normotensive" subject 8, 14, and 18.

The previous blood pressure variability provides impetus for ambulatory blood pressure monitoring (Drayer et al., 1985). Blood pressure peaks and the percentage of time above those critical levels may pose the greatest threats toone's cardiovascular system (Brenner et al., in press; Halberg et al., 1974; Loggie, New, & Robson, 1979; Pesinna, Palatini, Sperti, Cordone, Libardoni, Mas, Mormino, Di Marco, & Palú, 1985; Pickering et al., 1985; Scarpelli et al., 1985; Sinaiko, Bass, Marin, & Prineas, 1986).

This study monitored subjects for 24 to 48 hours. It is recommended that 48 hours be a minimum monitoring period. All but two systolic blood pressure profiles yielded a p value below 5% for the rejection of this study's two harmonics mathematical model. This longer period may also minimize possible novelty effects. Horan (1985) also

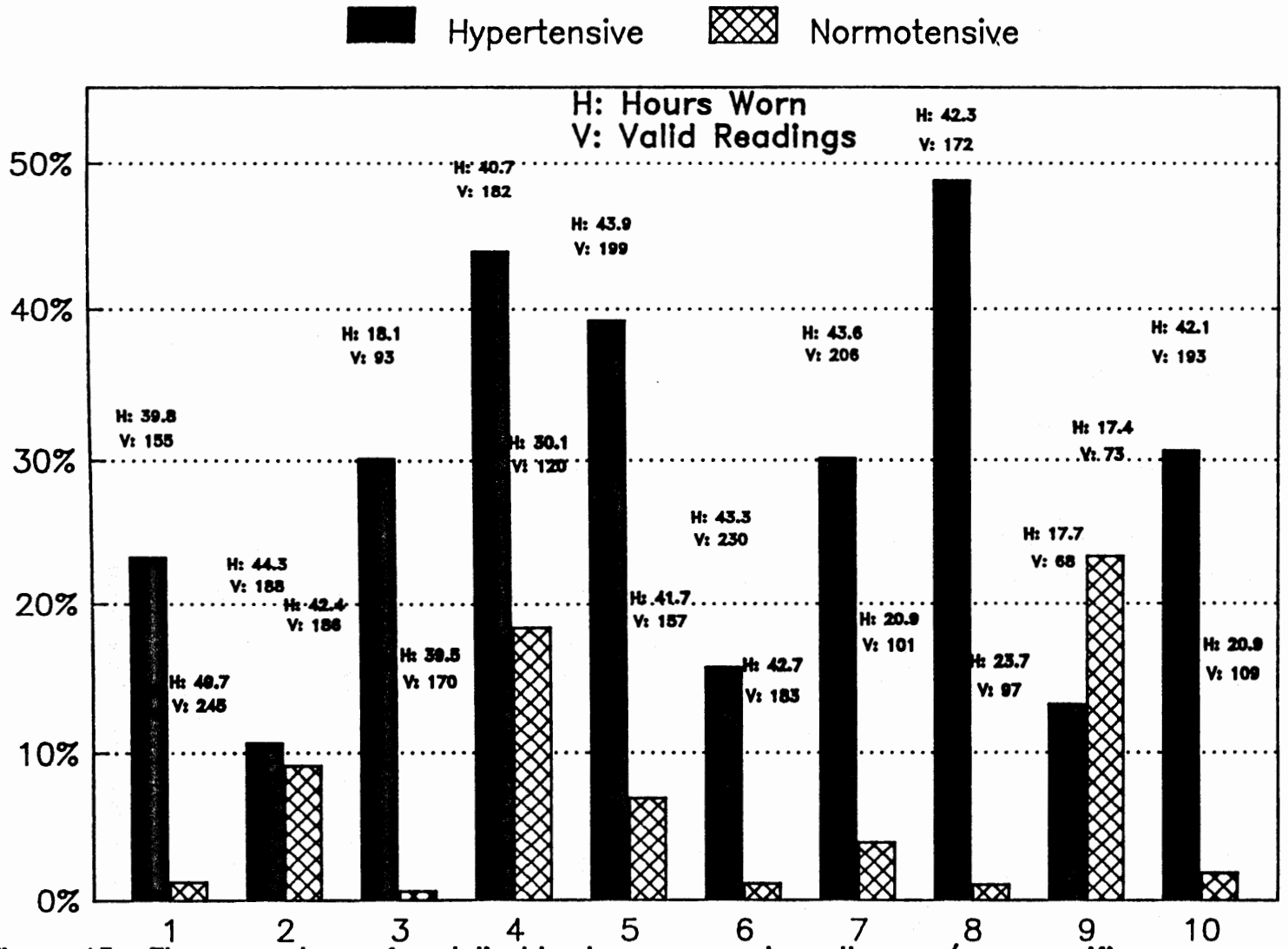

Figure 15. The percentage of systolic blood pressures above the age/sex-specific 90th percentile values when compared between the hypertensive-normotensive matched pairs.

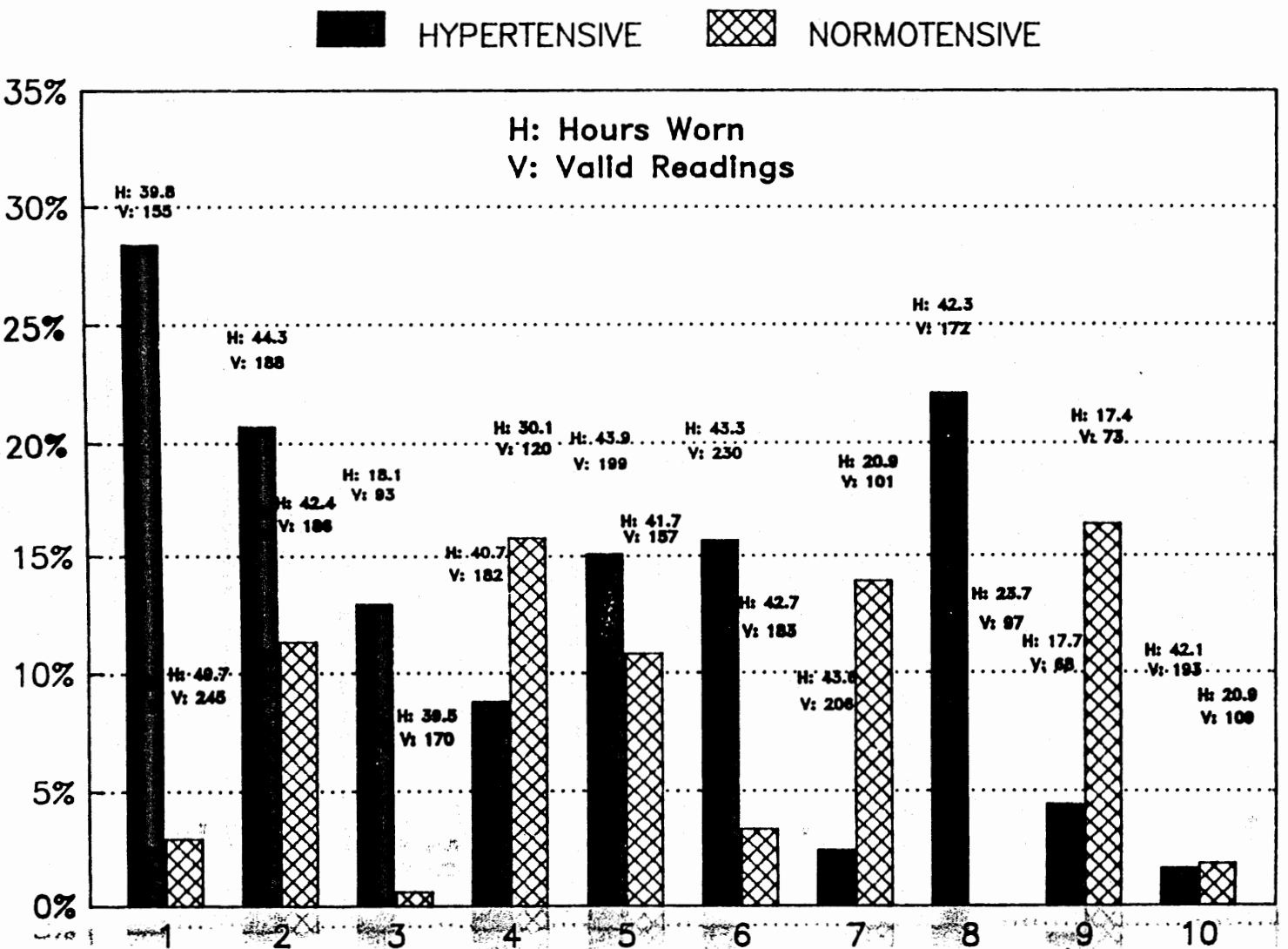

Figure 16. The percentage of diastolic blood pressures above the age/sex-specific 90th percentile values when compared between the hypertensive-normotensive matched pairs.

questioned whether a single 24 hour ambulatory blood pressure recording was reflective of an individual's usual blood pressure profile.

A matched pairs one-tailed t-test and equality parameter tests also indicated a significant difference in systolic blood pressure amplitude between the normotensive and hypertensive adolescents. Hypertensive systolic blood pressure variability may parallel the higher mesor levels in this sample. Diastolic blood pressure amplitude did not demonstrate a significant difference because it fluctuates to a lesser extent than does systolic blood pressure (Drayer et al., 1985).

Acrophase provided a perspective of circadian rhythmic coordination. Table 13 (page 123) indicated that even when parameters were either significantly phase advanced or phase delayed, there was consistency or coordination in this direction. It was also found that there was no relationship between blood pressure synchrony (as reflected by mean percent rhythm) and blood pressure level. The mean percent rhythm for the normotensive group was 36.8 as compared to 36.6 for the hypertensive group.

In conclusion, higher systolic blood pressure mesors and amplitudes were demonstrated by the hypertensive adolescents. As indicated by the circadian overall hyperbaric index, three of these individuals were also

determined to have significant pressure excesses. Despite this greater cardiovascular diversity and complexity, the circadian rhythms remained synchronous. The findings also support the Rogerian integrality principle and the Theory of Accelerating Evolution. As the hypertensive student continuously, mutually and simultaneously interacted with the environment, he/she was able to self-regulate and organize these more complex and diverse systolic blood pressure circadian patterns. The rhythms remained synchronous.

The previous findings cannot be generalized beyond these samples but may contribute to an adolescent cardiovascular circadian rhythm data base. Eventually, sensitive and accurate chronobiological parameters may be elucidated which will identify those adolescents at risk to develop hypertension before it is reflected in actual measurement elevations.

Although the SpaceLabs 90202 Monitor was determined to be a valid instrument in nonexercise situations, this conclusion should not be generalized beyond these samples and these settings. Of concern is the number of error codes generated by the device (see Table 16). Review of student activity diaries revealed that riding in or driving a car was responsible for 10% of these errors. The source(s) of a majority of the error codes must be identified before the

Table 16
SpaceLabs 90202 Monitor Summary

SUBJ #	ABPM #	INTERIM DAYS	TOT SCAN TIME(HRS)	# VALID RDGS	# EE	# AE	# INV	TOTAL	% EDITED
1	2	-	21.2	84	48	0	5	137	38.7%
1	6	7	18.6	71	75	5	4	150	56.0%
2	4	-	24.1	118	30	0	6	154	23.4%
2	3	1	25.6	127	33	1	2	162	22.2%
3	1	-	20.9	89	66	2	9	164	47.0%
3	1	-	23.4	99	61	2	8	168	42.3%
4	1	-	21.5	101	43	0	2	146	30.8%
4	6	7	20.9	85	47	0	2	134	36.6%
5	2	-	18.1	93	25	0	6	124	25.0%
6	6	-	21.5	105	33	0	0	138	23.9%
6	6	10	18.0	65	86	11	9	160	66.3%
7	6	-	18.8	87	46	0	9	142	38.7%
7	6	-	21.9	95	21	0	6	122	22.1%
8	3	-	22.8	79	87	2	9	175	56.0%
8	3	-	7.3	41	20	0	5	66	37.9%
9	3	-	23.8	109	33	4	7	149	29.5%
9	3	-	20.1	90	33	4	9	132	34.8%
10	6	-	22.8	90	60	1	11	161	44.7%
10	1	4	18.9	67	100	3	8	175	63.4%
11	6	-	19.7	108	25	1	0	133	19.5%
11	4	-	23.6	122	20	1	0	142	14.8%
12	6	-	20.4	80	72	0	4	156	48.7%
12	6	-	22.3	103	42	5	3	148	33.8%
13	6	-	23.6	111	38	2	7	156	30.1%
13	6	-	20.0	95	10	0	3	108	12.0%
14	6	-	20.9	101	57	0	13	171	40.9%
15	2	-	22.0	88	119	1	4	211	58.8%
15	2	-	20.3	84	54	1	4	142	41.5%
16	4	-	23.7	97	37	6	9	143	36.4%
17	6	-	17.7	68	29	1	6	103	35.0%
18	2	-	17.4	73	104	3	8	185	62.2%
19	1	-	22.0	104	20	0	5	129	19.4%
19	4	8	20.1	89	26	0	2	117	23.9%
20	3	-	20.9	109	37	1	9	155	30.3%

Note. EE: Subject terminated blood pressure measurement or measurement could not be obtained.
AE: Systolic/diastolic blood pressure or heart rate was outside limits established by investigator; code automatically generated by SpaceLabs unit.
INV: Data edited by investigator according to absolute or suspected artifact as defined in "Ambulatory Blood Pressure Edit Criteria".

unit's validity and reliability is completely established.

The nurse has a unique responsibility in making accurate and sensitive assessments concerning daily blood pressure fluctuations in adolescents with and without high blood pressure levels. He/she may then be able to make knowledgeable diagnoses concerning prevention and health promotion. Information is needed to: (a) determine blood pressure reference standards for various populations; and (b) design comprehensive yet cost-effective blood pressure screening programs. Continued nursing research in the area of cardiovascular circadian rhythmicity will also assist nurses in educating other health care professionals and the public as to the need for 24-hour ambulatory blood pressure monitoring.

Limitations

The following limitations were identified.

1. Lack of control of extraneous factors is a limitation inherent in chronobiological research. Attempts were made to minimize their effects by employing specific sample inclusion criteria. Immediately prior to connection to the SpaceLabs monitor, students were screened for factors which may also alter circadian rhythms i.e., travel outside the local time zone, recent illness, the onset ofmenstruation, wake/sleep cycle and medications. Brenner et al. (in press) suggest that wearing the unit in school

versus wearing it off campus may contribute to significant differences in the cardiovascular parameters.

2. Physical activity may have been temporarily altered. The students were cautioned to avoid strenuous exercise and contact sports because: (a) the SpaceLabs unit had not yet been tested under exercise conditions; and (b) the possibility of damage to the device.

3. There was loss of data because of frequent SpaceLabs error code generation. It was also difficult, if not impossible, to determine the reason(s) for this.

Recommendations for Further Study

Recommendations for future research are:

1. further establish the validity and reliability of the SpaceLabs 90202 Ambulatory Blood Pressure Monitor in a variety of populations, settings, and conditions. It would also be important to ascertain why error codes were being generated.

2. study replication with the exceptions of having the students wear the SpaceLabs device: (a) either in a school or off-campus setting; and (b) for a minimum of 48 hours.

3. employ ambulatory blood pressure monitoring in longitudinal blood pressure tracking studies.

4. analyze adolescent cardiovascular circadian rhythmicity in order to: (a) further contribute to a data base which may help define reference standards and

illuminate the complex factors modulating blood pressure; and (b) assess how a family history of hypertension, age, height/weight, and ethnicity might affect the 24-hour cardiovascular rhythms.

These recommendations are offered so that nursing may increase its knowledge base grounded in empirical evidence.

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APPENDIX A

Research Review Committee Form

TEXAS WOMAN'S UNIVERSITY
COLLEGE OF NURSING

PROSPECTUS FOR DISSERTATION

This prospectus proposed by: Anne C. Jacoby

_____ and entitled:

Cardiovascular Circadian Rhythms in Normotensive and Hypertensive Adolescents

Has been read and approved by the members of (his/(hers)) Research Committee.

This research is (check one):

_____ Is exempt from Human Subjects Review Committee review

because _____

_____

_____

✓ Requires Human Subjects Review Committee review

because A majority of the subjects are under 18 years of age

_____

Research Committee:

Chairperson Margie N Johnson

Member Helen A. Busch

Member Peggy J. Daso

Member Margaret T. Beard

Member Ellen Jennings

APPENDIX B

Approval Letter From Graduate School

TWU Texas Woman's University
P O Box 22479 Denton Texas 76204 (817) 898-3400 Metro 434-2863 Tex-An 341-3400
THE GRADUATE SCHOOL

September 29, 1987

Ms. Anne C. Jacoby
3400 Fallmeadow, #3218A
Denton, TX 76201

Dear Ms. Jacoby:

I have received and approved the Prospectus for your research project. Best wishes to you in the research and writing of your project.

Sincerely yours,

Leslie M. Thompson

Leslie M. Thompson
Provost

dl

cc Dr. Margie Johnson
Dr.Anne Gudmundsen

APPENDIX C

Approval Letter from Health Magnet High School

April 9, 1987

To: Dr. Richard Adams
Director, Human Health Services
Dallas Independent School District
3700 Ross Avenue, Room 206
Dallas, Texas 75204

From: Anne C. Jacoby, R.N., M.S.N., Cardiovascular Nurse Specialist, Doctoral Candidate -- Texas Woman's University
1530 Gunnison Trail
Lewisville, Texas 75067

Dear Dr. Adams:

Your signature below confirms that you have given me verbal permission to conduct the following studies at High School for the Health Professions in Dallas: 1) a blood pressure screening program; and 2) assessment of adolescent cardiovascular circadian rhythms via the Space Labs Model 90202 Ambulatory Blood Pressure Monitor.

R M Adams 4-13-87

Dr. Richard Adams Date

Thank you again for your time and support.

Sincerely,

Anne C. Jacoby

Anne C. Jacoby

APPROVED:

Bruce Norman

Bruce Norman
Principal

APPENDIX D

Instructions While Wearing the SpaceLabs 90202 Monitor

Instructions While Wearing the

SpaceLabs 90202 Monitor

1. The ambulatory blood pressure unit has been programmed to **RECORD** your blood pressure and heart rate: 1) every 10 minutes from 6 AM to 12 midnight; and 2) every 20 minutes from 12 midnight to 6 AM.

2. If symptoms such as headaches or dizziness should occur between the readings, push the **blue** START/STOP button on the monitor and an additional reading will be taken. Readings will then continue on a normal cycle. Be sure to describe the symptoms in the Activity Diary.

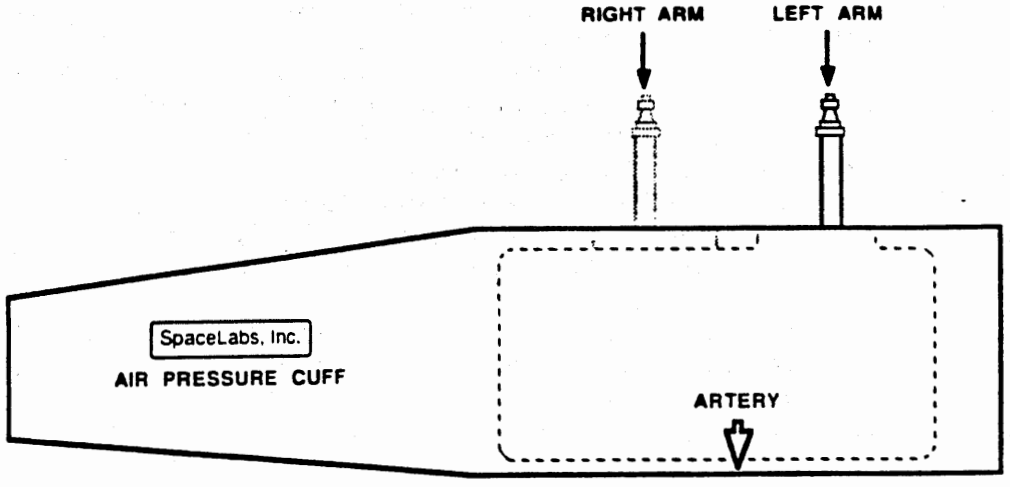
3. You will hear two tones informing you that the blood pressure cuff is about to inflate. At these sounds, stop what you are doing and straighten the cuffed arm by your side.

4. If your arm should become too uncomfortable during cuff inflation, press the **blue** START/STOP button. The blood pressure cuff should reinflate in 2 minutes.

5. If the cuff should stop or if you decide to remove the unit, please call me FIRST at BEEPER # 425-1606. After dialing this number, you will hear a tone three times. Immediately dial the phone number where you may be reached, then hang up. (**NOTE: This procedure requires a push button phone.**) If you do not have a push button phone, my home phone number is ___-____. I will return your call as quickly as possible. If you want to remove the monitor because of machine malfunction, perhaps by troubleshooting together, the problem can be solved.

6. If the cuff should slip, turn the **black** ON/OFF switch to OFF. Disconnect the hose from the monitor with a counter-clockwise rotation. Have someone reapply the cuff hose to the same arm. The cuff hose may be positioned for either the right or left arm as shown below. The cuff should be securely placed on the upper arm. Relax your arm at your side. (The cuff is tight enough if you can only fit one finger between it and your arm.) Position the hose as previously demonstrated. Connect it to the monitor with a clockwise-turning motion. Gently pull on the

hose to ensure that connection is secure.



Move the black ON/OFF switch to ON. Put unit into carrying case. Push the blue START/STOP key and verify a monitor reading as previously demonstrated.

Please document the procedure in your activity diary.

7. The following list defines monitor error codes.

EC00: Blood pressure could not be detected.
EC01: Blood pressure determination not possible due to insufficient inflation of cuff.
EC02: Time-out has occurred before a pressure measurement could be taken.
EC03: Blood pressure measurement was canceled by the patient.
EC04: Measurement could not be completed within 115 seconds.
EC05: Loss of power during a reading.
EC06: Low battery condition; measurement was canceled. The LCD displays the letters LLL, and a one-second alarm sounds.
EC07: Low backup battery condition.
LLL: See EC06.

8. If "LLL" is displayed and an alarm sounds, immediately turn off the monitor to save the data in memory (turn the black ON/OFF switch to OFF). Replace the batteries as instructed below:

<u>After turning off the unit:</u>
a. Turn the rectangular looking latches on the rear

panel to unlock the battery access panel.

b. Replace the four C-cell main batteries. Correct battery placement is shown inside the access panel. Verify the polarity.

c. After replacing the batteries, gently close the rear access panel and secure the latches.

d. Turn on the monitor by turning the black switch to ON. Check that the display is on. If there is no display, turn off the monitor and call me immediately at beeper # 425-1606.

9. Driving a car may make it difficult for an accurate blood pressure measurement to be taken. Therefore, you may need to press the blue START/STOP button. In the Activity Diary, document that you are driving or riding in a car.

10. Do not remove the blood pressure monitor from the carrying case unless otherwise instructed.

11. UNDER NO CIRCUMSTANCES are you to bathe or shower while wearing the device. A sponge bath is permitted. (Should the monitor get wet, however, there is NO danger of electrical shock).

12. For the 24 hours, please try to maintain as near a normal schedule (eating, sleeping, etc.) as possible.

13. Should you become ill or stay up all night, your daily fluctuations in blood pressure and heart rate will be affected. Therefore, after turning off the unit, remove it and the cuff. Then call me via my beeper.

14. Because of possible damage to the monitor, please refrain from contact sports and extended periods of physical exertion while wearing it.

15. Please return to the Cardiology Department's computer room on _____ at _____ : _____ (AM PM).

If you should have ANY additional questions or concerns, please do not hesitate to contact me via my beeper. This includes any concerns with the blood pressure and/or heart rates the unit displays. Your participation, interest, and support are GREATLY APPRECIATED.

Sincerely,
Anne C. Jacoby

APPENDIX E

Ambulatory Blood Pressure Monitor Class Outline

AMBULATORY BLOOD PRESSURE

MONITOR CLASS OUTLINE

I. Introduction

A. High blood pressure statistics

B. Definitions

1. Blood pressure

2. High blood pressure

C. Objectives of past adolescent blood pressure studies

II. Rationale for Student Selection

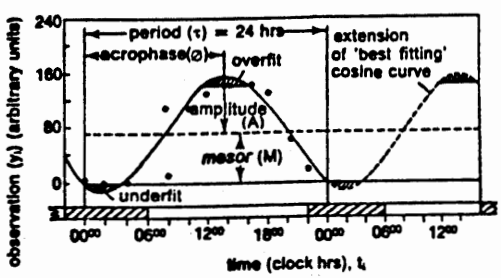
A. Delimitations

B. Samples

III. Overview of Circadian Rhythm Study

A. Importance

B. Definitions
1. Circadian rhythm
2. Mesor
3. Amplitude
4. Acrophase



C. Instruments
   1. SpaceLabs 90202 Ambulatory Blood Pressure Monitor

   2. Activity Diary with instructions

   3. UTAH Family History Scale

D. Schedule
   1. Contacted one week prior to wearing blood pressure monitor
      a. Confirmation
      b. Determination that student presently meets inclusion criteria
   2. Payment protocol
   3. Time-frame

IV. Results

A. Individual report

B. Study abstract

V. Conclusion

A. If interested, complete the 3" x 5" card with name, address, phone number, and parent/guardian name.

B. Distributed consent forms will be picked up from cluster teachers by _____. If necessary, contact me at beeper #425-1606. After dialing this number, you will hear a tone three times. Immediately dial the phone number where you may be reached, then hang up. (NOTE: This procedure requires a push button phone.) I will return your call as quickly as possible.

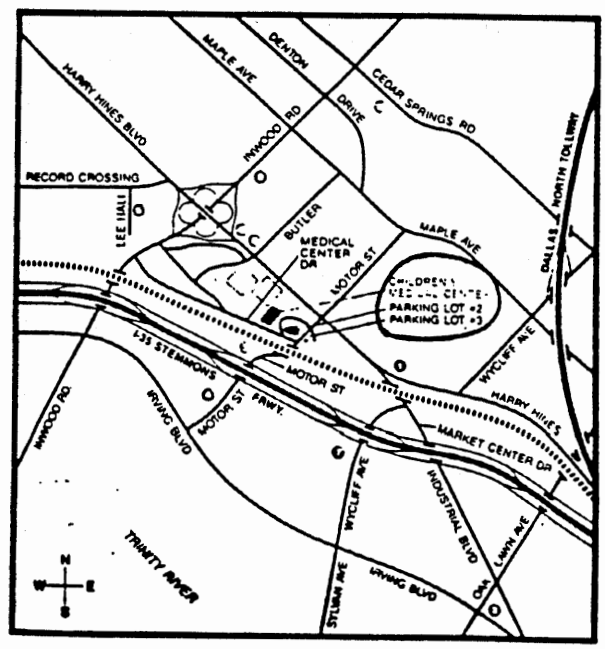
APPENDIX F

Letter to Student

Dear _____:

Here is the map locating Children's Medical Center. Parking lots 2 & 3 are for visitors. If someone is bringing you, parking will cost approximately $ 2.00. They are welcome to come to the office with you. Take the elevators to the sixth floor. Ask one of the secretaries or nurses at the nurse's station for directions to Dr. Fixler's office in the Cardiology Department. I will be waiting to take you to the computer room where the ambulatory blood pressure monitor will be put on.

If you have any questions, please do not hesitate to page me via my beeper (phone number: 425-1606). After dialing this number, you will hear a tone three times. Immediately dial the phone number where you may be reached, then hang up. (NOTE: This procedure requires a push button phone.)



As mentioned on the phone, we will discuss the written instructions/comments concerning the unit you will be given. I will also review the activity diary and the health family history questionnaire. At the conclusion of this meeting, I want to give you a sheet on which I would like you to share your comments and criticisms about wearing the blood pressure unit for one day.

It is my intention to make this project as informative, fun, and as easy as possible for you and your family. You will be sent a report of: 1) your blood pressure readings; and 2) recommended changes and comments offered by the other students participating in this study. A check made out to you will also be included. Just a reminder, the $ 60.00 in

computer analyses will be done at NO COST to you.

Thank you, and I look forward to seeing you _____, _____ at ____:____ (AM PM).

Sincerely,

Anne

Anne Jacoby

P.S. Disconnecting time will be at ____:____ (AM PM) the following day, and should only take 30 minutes.

APPENDIX G

Letter Requesting Parental Consent

LETTER REQUESTING PARENTAL CONSENT

From: Anne C. Jacoby, R.N., M.S.N., Cardiovascular Nurse Specialist
Doctoral Candidate
Texas Woman's University
Denton, Texas 76204

Date:

Dear Parent or Guardian:

Over 400 students participated in the Texas Woman's University/Southwestern Medical School Cooperative Blood Pressure Screening Program. The results were recently given to your youngster to share with you.

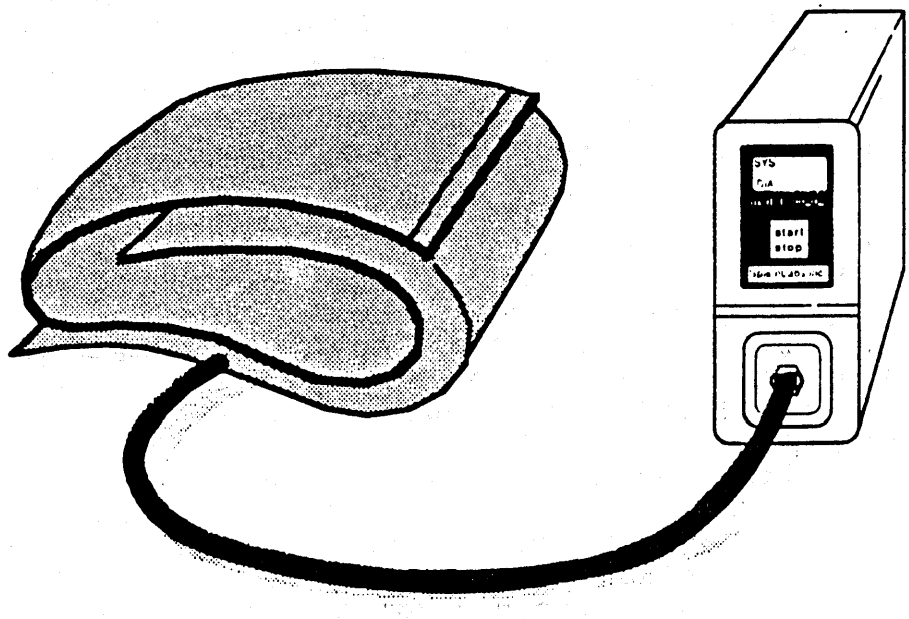
Your son/daughter has been selected from the above population to participate in a study which will monitor blood pressure over a 24-hour period. They were chosen because they: 1) have a normal blood pressure and a family history of hypertension; 2) have a normal blood pressure level without such a family history; or 3) have high blood pressure as determined by three separate blood pressure measurements.

In some instances, there was some variation among the student's three blood pressure measurements. Although it is known that blood pressure normally fluctuates throughout the day, there are no criteria specifying <u>when</u> or <u>how long</u> blood pressure must be elevated to confirm a diagnosis of hypertension.

The real problem of accurate diagnosis of hypertension, then, is determining which data to use. In other words, "Can you take a blood pressure reading at any particular time of the day and know, with confidence, that the reading accurately reflects the person's health?"

To better understand this question, your son/daughter has agreed to wear a portable blood pressure unit for one 24-hour day. The SpaceLabs 90202 Ambulatory Blood Pressure Monitor (pictured on page 2) is a small, lightweight instrument designed to take blood pressure and heart rate measurements on an outpatient basis for 24 to 48 hours. The blood pressure and heart rate will be taken by a blood pressure cuff attached to your son/daughter's arm. The blood pressure unit's analysis system has programmed the monitor to take the blood pressure and heart rate every 10

minutes throughout the 24-hour period. The blood pressure cuff will self-inflate after your son/daughter hears two tones indicating the cuff is about to inflate. He/she will straighten his/her arm at that time. It will take about 10 seconds for the cuff to fully inflate; the cuff will then gradually deflate as it measures the blood pressure and heart rate. These measurements will be shown on the instrument's front panel and also recorded in the unit's memory. The portable blood pressure unit is carried in a pouch and will be strapped and/or belted at your youngster's side.



Your youngster will be asked to keep an Activity Diary while wearing the blood pressure monitor. It will contain brief notations of what he/she was doing while the cuff was inflating; this documentation will help me interpret the data. He/she will also complete and have family members complete the "Health Family Tree." This form, developed by Baylor College of Medicine in Houston, seeks to validate the effectiveness of family history in predicting future disease.

While wearing the ambulatory blood pressure unit,there: 1) may be some arm discomfort with cuff inflation; 2) will be the need to temporarily stop an activity during cuff

inflation and deflation; 3) will be the need to refrain from water activities (including baths and showers); and 4) may be slight sleep disruption secondary to the unit's noise during cuff inflation. Efforts to minimize these situations include: 1) holding the arm straight at one's side during arm cuff inflation and deflation; 2) permitting sponge baths, as necessary while wearing the ambulatory blood pressure monitor; 3) programming the monitor tone to be off from 12:00 midnight to 6:00 AM; 4) conducting a pilot study with 12 students (their comment/suggestions concerning their likes and dislikes will be considered for inclusion in this study); 5) providing written information which will include a Problem Solving Checklist and instructions on how to remove the unit should you or your youngster desire or feel it necessary to do so; 6) changing the cuff inflation interval time to promote comfort; and 7) being available to you and your youngster via a "beeper" should questions or problems arise.

Your son/daughter will be fitted to and disconnected from the blood pressure monitor at Children's Medical Center (next to Parkland Memorial Hospital) or the high school. A map specifying directions to the hospital will be mailed to him/her. I will call your youngster to arrange a time for the unit to be worn. The Health Family Tree and blood pressure/heart rate measurements will be computer analyzed at no cost to you. You will receive a written report of these findings. Your youngster will be monetarily compensated for his/her participation in this study. A $15.00 check will be made to the order of him/her only after the unit has been worn for the entire 24 hours. The twelve students participating in the pilot study will receive an additional $10.00 as will twelve other students asked to wear the blood pressure monitors for a total of 48 hours. However, no medical service or compensation will be provided by Texas Woman's University as a result of injury from participation in this research.

Any information that is obtained in connection with this study and that can be identified with you or your son/daughter will remain confidential. It will be disclosed only with permission from you and your youngster. All data will be assigned a code number to insure anonymity. The findings will be shared with other health professions. Better understanding blood pressure -- its fluctuations and how hypertension can best be diagnosed -- is extremely important in promoting health and in minimizing the possible complications of high blood pressure.

If you are interested in your youngster participating in this study, please sign this consent form and return it to me in the attached stamped, addressed envelope. If you or your son/daughter decide to withdraw after signing, it is all right to do so. You will be given a copy of this letter to keep. Also, please complete or have those immediate family members who have high blood pressure complete the "Family History of High Blood Pressure" section on page 5.

If you have any questions, please do not hesitate to page me via my beeper (phone number: 425-1606). After dialing this number, you will hear a tone three times. Immediately dial the phone number where you may be reached, then hang up. (Note: This procedure requires a push button phone.) I will return your call as quickly as possible. Thank you again for your time and consideration.

Sincerely,

Anne Jacoby

Anne C. Jacoby

I, (please PRINT name) _____ , agree to participate in the blood pressure data collection program administered and conducted by Anne C. Jacoby.

_____ _____
(Youngster's signature) (Street Address)

_____ _____
(Birthday) (City)

_____ _____
(Area Code) Phone Number (State) (ZIP)

I give my consent to allow _____ to participate in the above-mentioned program.

_____ _____
(Parent/Guardian's Signature) (Date)
(Relationship)

==========

Family History of High Blood Pressure

DEAR PARENT/GUARDIAN: Please indicate below those individuals in your immediate family who have hypertension. Immediate family refers to your son(s), daughter(s), the mother or father of the student participating in this study, and yourself. Include the following information for each individual: 1) relationship to student participant; 2) the blood pressure (if known); 3) how long he/she has had high blood pressure; 4) if the person is under a doctor's care; and 5) is blood pressure medication required. If there is no hypertension in the immediate family, write "Does not apply."

Person's Name	Relationship	Blood Pressure	Doctor's Care	On Medication
.....	.....	.....	....	.....
.....	.....	.....	....	.....
.....	.....	.....	....	.....
.....	.....	.....	....	.....
.....	.....	.....	....	.....
.....	.....	.....	....	.....

APPENDIX H

SpaceLabs 90202 Monitor Reliability/Calibration Protocol

SpaceLabs 90202 MONITOR
RELIABILITY / CALIBRATION PROTOCOL

Reliability Check

1. The subject will be sitting comfortably in a chair.

2. A mercury sphygmomanometer has been calibrated by the Bio-medical Instrumentation Department at Children's Medical Center. This instrument is on a stand. It is placed on the subject's nondominant side in close proximity to his/her arm.

3. The cuff has been applied to the nondominant arm according to American Heart Association (1980) criteria.

4. The T-tube (SpaceLabs P/N 016-0040-00) is attached to the monitor. The remaining T-tube parts are for the monitor's hose and the sphygmomanometer's tubing.

5. Completely close (turn clockwise) the valve attached to the sphygmomanometer's bulb.

6. Have the subject hold the bulb with the nondominant hand. Have the student hold the unit in the other hand so that the LCD can be seen only by him/her.

7. The investigator will obtain a heart rate (see Appendix N) which will be documented on the Blood Pressure Instrument Information sheet (see Appendix H).

8. The investigator will then apply a Sprague-Rappaport stethoscope over the student's brachial artery.

9. She will turn the unit's OFF/On switch to "ON" and

depress the blue START/STOP button.

10. The investigator will remain eye level with the mercury column during cuff deflation. She will record the first and fifth Korotkoff sounds (American Heart Association, 1986). This measurement is recorded on the Blood Pressure Instrument Information sheet. Because the "bleed step" is 4 mm Hg, 2 mm Hg is added to these auscultatory blood pressure measurements. Auscultatory and oscillometric techniques must compare within 6 mm Hg of each other for both systolic and diastolic blood pressures.

11. A single tone indicates that the unit has obtained the blood pressure/heart rate measurements. The investigator will then read these numbers shown on the LCD and write them on Appendix H.

Calibration Check

1. After one to two minutes, the investigator will again depress the START/STOP button. This time, the LCD will be visible as the cuff deflates; the monitor's measurements will be seen on the LCD and should compare within 3 mm Hg of the manometer readings. In addition, the mercury should descend and the cuff should deflate in the 4 mm Hg programmed "bleed step". The student will be told that there may be an occasional 3 to 5 mm Hg difference between the discrete measurements seen on the LCD. If this difference is consistently 6 to 8 mm Hg, the subject will be

instructed to turn the unit off and page the investigator via her beeper.

2. At the end of this procedure the monitor, air hose, and sphygmomanometer are disconnected from the T-tube. The hose is then reconnected to the monitor.

APPENDIX I

Demographic Information

DEMOGRAPHIC INFORMATION

NAME:_____ DATE:___/___/___ DAY:_____
STUDY: __ Pilot __ Main __ Reliability
CODE #:____ GROUP: __ Hyper..... __ Match-Normo
__ +FH/Both..... __ Match-Normo
Sex:___ __ +FH/Fa..... __ Match-Normo
Age:___ __ +FH/Mo..... __ Match-Normo

BP AT SCREENING: ____/____ ____/____ ____/____

IF HYPERTENSIVE:

Blood Pressure:
- Arm BP: ____/____
- Thigh BP: ____/____

Femoral Pulse Related to Radial Pulse:
- Delay: _____ No Delay: _____
- Diminished: _____ Not Diminished: _____

Within last 2 weeks, travel outside time zone:
___ Yes ___ No
any illness: ___ Yes ___ No

DATE: ___/___/____ DATE: ___/___/____
Time arise: ___:___ (AM PM) Time arise: ___:___ (AM PM)
Time asleep:___:___ (AM PM) Time asleep:___:___ (AM PM)

Medications:_____
_____

Comments:_____
_____

APPENDIX J

Blood Pressure Instrument Information

BLOOD PRESSURE INSTRUMENT INFORMATION

NAME: _____ CODE #: _____

ABPM #:_____ ABPM Serial #:_____ Arm: ___ Lt ___ Rt

1. Date/Time of Unit Hook-Up: __/__/__ at ___:___ (AM PM)

Heart Rate:
. Radial HR: _____ / 30 sec. x 2 = _____ BPM
(Taken immediately before unit bp cuff inflation)
. SpaceLabs Monitor HR: _____ BPM

Blood Pressure:
. Auscultatory: SBP _____ DBP _____
. SpaceLabs Monitor: SBP _____ DBP _____

Calibration Checklist:

___ instrument deflates in 4 mm Hg increments

___ as the cuff deflates, bp measurements between the SpaceLabs unit and the standard mercury sphygmomanometer compare within 3 mm Hg of each other

2. Date/Time Unit Disconnected: __/__/__
at ___:___ (AM/PM)

Heart Rate:
. Radial HR: _____ / 30 sec. x 2 = _____ BPM
(Taken immediately before unit bp cuff inflation)
. SpaceLabs Monitor HR: _____ BPM

Blood Pressure:
. Auscultatory: SBP _____ DBP _____
. SpaceLabs Monitor: SBP _____ DBP _____

Calibration Checklist:
___ instrument deflates in 4 mm Hg increments

___ as the cuff deflates, bp measurements between the SpaceLabs unit and the standard mercury sphygmomanometer compare within 3 mm Hg of each other

APPENDIX K

Activity Diary

(Available Upon Request)

APPENDIX L

SpaceLabs 90202 Monitor Description and Application

SpaceLabs 90202 AMBULATORY BLOOD PRESSURE MONITOR

Description

The SpaceLabs (Redmond, WA) Ambulatory Blood Pressure Monitor (ABPM) is an 8.6 x 3.9 x 14.5 cm unit weighing 25 ounces. The portable outpatient monitor is carried in a pouch and is strapped and/or belted at the individual's side. The monitor front panel includes the liquid crystal display (LCD), arm cuff hose connector, and START/STOP button. The rear panel has the communications port connector and battery access panel. The "Risk Class 2" designation indicates the unit meets or exceeds international standards for isolating the subject from electrical connection. The unit's top panel provides abbreviated operating instruction, model and serial numbers, and labels for PROGRAM INPUT/DATA OUTPUT and clock battery. The ON/OFF switch is at the side of the monitor.

The device's analysis system programs the instrument to take the blood pressure and heart rate at designated frequencies for 24 to 48 hours. These parameters are obtained by a blood pressure cuff attached to the subject's arm. They are recorded by the monitor and then transmitted to a SpaceLabs ambulatory blood pressure analysis system for report generation.

When either a subject-initiated or programmed blood pressure reading is taken, the monitor first emits two brief tones to alert him/her that the blood pressure cuff will self-inflate in five seconds. The subject then drops the cuffed arm loosely to the side. Cuff inflation time averages ten seconds but may vary with cuff size and fitting. Deflation time is dependent upon the blood pressure and the programmed deflation rate (bleed step). A microprocessor handles the: (a) time-programmed cuff inflation; (b) processing of oscillometric blood pressure signals; and (c) data storage of up to 240 readings. Four alkaline C-cell (1.5 V) batteries power the unit.

One tone signals the end of cuff inflation. The heart rate, and systolic/diastolic/mean arterial pressures are recorded in the unit. However, only the heart rate and systolic/diastolic blood pressure are displayed three times on the LCD. This display is optional. Military time is visible on the LCD except: (a) during cuff inflation and deflation; and (b) when the heart rate and systolic/diastolic pressure measurements are being generated.

The SpaceLabs 90202 (ABP) Monitor has the following parameters:

Blood Pressure Range

Systolic:	70 to 290 mm Hg
Diastolic:	40 to 150 mm Hg
Mean:	60 to 240 mm Hg

Heart Rate Range

40 to 180 beats per minute

For this study, the unit's default settings are:

Auto Edit	Maximum	Minimum
Systolic	260	70
Diastolic	150	40
Pulse Pressure	100	20
Heart Rate	200	20

First Application

A. Before the subject arrives:

1. Install four new C-cell 1.5V batteries into the SpaceLabs 90202 Monitor as illustrated on its rear panel.

2. The ABP analysis system initializes the unit as specified in the SpaceLabs, Inc. Operations/Technical Manual (1986).

3. Select the proper size cuff for the subject. (His/her midarm circumference was obtained and recorded during a blood pressure screening program.) SpaceLabs arm blood pressure cuff sizes are as follows:

CUFF SIZE	ARM CIRCUMFERENCE
Small adult	18 to 26 cm
Average adult	25 to 35 cm
Large adult	33 to 47 cm

4. Assemble the subject's packet (Appendices B, G through I, and K).

5. Put four reserve C-cell alkaline batteries in a box

for him/her to take home. If the batteries have been used, they are tested for adequate voltage (see Appendix M).

B. When the subject arrives:

1. Review the packet and the SpaceLabs monitor in the school nurse's office or in an examining room at the hospital. The student's unit is available for demonstration and referral. (NOTE: The investigator demonstrates how: (a) she is paged via the beeper; and (b) the four reserve batteries are inserted.)

2. At the conclusion of the one hour informal meeting, the investigator calibrates and obtains unit/mercury sphygmomanometer comparison measurements as delineated in Appendix F. The cuff has been positioned on the subject's nondominant arm according to American Heart Association criteria (1980). The investigator demonstrates this placement (Appendix B, item 6) and how the hose is connected to the unit.

3. The monitor is placed in its carrying pouch and the strap is snapped on. The subject is given the option of wearing the device around the neck or waist, or over the shoulder.

4. Confirm the next appointment date and time.

<u>Second Application</u>

A. Before the subject arrives:

1. Boot the Zenith Z-183 PC and access the SpaceLabs

computer program in accordance with the Operations/Technical Manual (SpaceLabs, Inc., 1986).

2. Prepare a second packet containing Appendices G through I.

B. When the subject arrives:

1. Calibrate and obtain comparison blood pressure measurements as previously described.

2. Turn the unit off and remove it from the carrying pouch. Disconnect the hose by turning the black knob counter-clockwise. Have the student remove the cuff.

3. Discuss with the student his/her comments and criticisms concerning the project.

4. Download the data from the unit to the Zenith Z-183 PC according to instructions contained in the Operations / Technical Manual (SpaceLabs, Inc., 1986). Discuss the blood pressure and heart rate measurements with the subject as they are displayed on the computer screen.

5. Ask the subject if he/she is interested in wearing the unit for a second day. The primary reason given will be the novelty effect. Therefore, additional data should provide a more complete and accurate picture of the blood pressure trends just seen since the unit will be measuring normal blood pressure fluctuation and not the adjustment to the device.

6. If the student is hypertensive, obtain a thigh blood

pressure measurement (see Appendix P).

7. Answer any questions.

8. Reinitialize the unit.

9. Reapply cuff and connect the hose to the monitor.

10. Reinsert the device into the pouch and strap in place according to subject preference. When he/she returns the following day, repeat steps A-1 and B-1 through B-5.

APPENDIX M

Student Evaluation of Study

STUDENT EVALUATION OF STUDY

If you chose,you may respond anonymously to the questions below.

1. Were instructions / explanations clear? _____ Yes ____ No

   If no, where was clarity lacking?
   _____ SpaceLabs Unit
   _____ Activity Diary
   _____ Health Family Tree
   _____ Other

   Please elaborate: _____
   _____
   _____
   _____

2. What did you like most about the project and why?

3. If you were to participate again in the study, what would you change and why?

Other comments: _____
_____
_____
_____
_____

Thank you! Your comments / suggestions, time, and cooperation are most appreciated.

APPENDIX N

Ambulatory Blood Pressure Edit Criteria

Ambulatory Blood Pressure

Edit Criteria

Type I - ABSOLUTE ARTIFACT

1. A diastolic blood pressure $\leq$40 or $\geq$140 mm Hg
2. A systolic blood pressure $\leq$70 or $\geq$245 mm Hg
3. A pulse pressure $\leq$10
4. A recorded diastolic pressure that registered higher than systolic pressure
5. A sudden increase (more than 40 mm Hg systolic or 20 mm Hg diastolic) in blood pressure concomitant with exposure to an environmental source of artifact (driving, construction, etc.) as indicated by diary.

TYPE II - SUSPECTED ARTIFACT

1. Blood pressure measurements deemed possible but unlikely because they deviated from the individual's trend pattern of blood pressure measurements and occurred immediately before or after a Type I artifactual measurement.
2. Blood pressure measurements deemed possible, but the recorded diastolic pressure was greater than the preceding and subsequent systolic pressure measurement.
3. Blood procedure measurements deemed possible, but an abrupt increase in pressure (more than 40 mm Hg systolic

or 20 mm Hg diastolic) was not accompanied by an increase in heart rate of at least one beat per minute.

APPENDIX O

Battery Testing Protocol

BATTERY TESTING PROTOCOL

Equipment

Model 630 Voltmeter
Triplett Electrical Instrument Co.
Bluffton, Ohio

Procedure

Step 1. Turn the red dial to "X1000" and touch voltage meter probes together. Needle should read "3" on the red DC scale.

Step 2. Turn the red dial to "3" and apply probes to the matching battery polarities. Needle should register greater than or equal to 1.5 on the DC scale. This indicates the batteries to be sufficiently charged.

Step 3. Turn the red dial to "OFF".

APPENDIX P

Heart Rate Protocol

HEART RATE PROTOCOL

Subject Preparation

The pulse measurement is obtained only after the subject has been quietly seated in an erect but comfortable posture for at least five minutes.

Procedure Outline

Step 1. The elbow and forearm are resting comfortably on the subject's thigh.

Step 2. With the palm turned upward, the radial pulse is palpated.

Step 3. The seven-jewelled Clebar stopwatch is started and the radial pulse counted for 30 seconds.

Step 4. The stopwatch is stopped. The number of beats in 30 seconds is recorded, multiplied by 2, and the product recorded as the heart rate in beats per minute on the Blood Pressure Instrument Information sheet.

APPENDIX Q

Arm Blood Pressure Measurement Protocol

ARM BLOOD PRESSURE

MEASUREMENT PROTOCOL

Equipment

Select a cuff and bladder as recommended by the American Heart Association (1980). Use a Sprague-Rappaport stethoscope. Record the findings on the Demographic Information sheet.

Subject Preparation

Subject should be in a sitting position with legs uncrossed.

Procedure Outline

Step 1. Position subject's arm at heart level.

Step 2. Apply cuff to upper arm with its lower edge approximately 2.5 cm above the antecubital aspect. Position bladder over the brachial artery.

Step 3. Palpate the brachial artery. Place the diaphragm of a Sprague-Rappaport stethoscope firmly over the artery, avoiding the cuff edge or clothing. Do not occlude the artery.

Step 4. Inflate the cuff to a pressure approximately 30 mm Hg above the subject's systolic pressure.

Step 5. Deflate cuff at a rate of 2 to 3 mm Hg/second to insure accurate determination of Korotkoff sounds.

Step 6. Note the first Korotkoff sound as the systolic

pressure and the fifth Korotkoff sound as the diastolic pressure (Report of the Second Task Force on Blood Pressure Control in Children, 1986). Read each pressure to the nearest 2 mm Hg. Any reading appearing to fall exactly between the mercury column markings should be read to the next highest marking (Program on the Epidemiology of Blood Pressure in Childhood, Youth and Early Adulthood, 1985). All readings are made at the top of the mercury column's meniscus.

Step 7. Deflate cuff completely and remove from subject's arm.

Step 8. Record systolic and diastolic measurements on the subject Demographic Information sheet.

APPENDIX R

Thigh Blood Pressure Measurement Protocol

PROTOCOL FOR THIGH BLOOD PRESSURE MEASUREMENT

Equipment

A thigh blood pressure cuff with a bladder width and length of 20 and 42 cm respectively (American Heart Association, 1980) is selected. If necessary, a larger thigh cuff is employed so that the lower third of the thigh is sufficiently encircled with the cuff to prevent ballooning. Use a Sprague-Rappaport stethoscope. Record the findings on the Demographic Information sheet.

Subject Preparation

Subject should be prone. If he/she cannot lie on the abdomen, the leg is flexed slightly (Bates, 1979).

Procedure Outline

Step 1. If possible, have the subject in a prone position.

Step 2. Apply cuff to the lower third of the thigh. Position bladder over popliteal artery.

Step 3. Palpate the popliteal artery. Place the diaphragm of the Sprague-Rapport stethoscope firmly over the artery, avoiding the cuff edge or clothing. Do not occlude the artery.

Step 4. Inflate the cuff to a pressure approximately 30 mm Hg above the subject's systolic pressure.

Step 5. Deflate cuff at a rate of 2 to 3 mm Hg/second to insure accurate determination of Korotkoff sounds.

Step 6. Note the first Korotkoff sound as the systolic pressure and the fifth Korotkoff sound as the diastolic pressure (Report of the Second Task Force on Blood Pressure Control in Children, 1986). Read each pressure to the nearest 2 mm Hg. Any reading appearing to fall exactly between the mercury column markings should be read to the next highest marking (Program on the Epidemiology of Blood Pressure in Childhood, Youth and Early Adulthood, 1985). All readings are made at the top of the mercury column's meniscus.

Step 7. Deflate cuff completely and remove from subject's thigh.

Step 8. Record systolic and diastolic measurements on the subject Demographic Information sheet.

APPENDIX S

SpaceLabs 90202 Monitor Validation Study

Raw Data Sheet -- Intensive Care Unit

SPACELABS 90202 MONITOR VALIDATION STUDY

RAW DATA -- INTENSIVE CARE UNIT

Name: _____ Date: _____
Diagnosis: _____ Age: _____
Computer: _____ DOB: _____
Hospital#: _____ Sex: ____ M ____ F

Time	Auscultation	Dinamap	SpaceLabs	SBP			DBP			HR
				MAX	MIN	MEAN	MAX	MIN	MEAN	

Arm circumference: _____

BP cuff size: _____

ABPM #: _____

Arterial line placement: _____

Limb: _____

Type/size cath: _____

Comments: _____

APPENDIX T

SpaceLabs 90202 Validation Study

Raw Data Sheet -- Catheterization Lab

SPACELABS 90202 MONITOR VALIDATION STUDY

RAW DATA -- CATHETERIZATION LAB

Name: _____ Date: _____
Diagnosis: _____ Age: _____
Computer: _____ DOB: _____
Hospital#: _____ Sex: ____ M ____ F

Reading	Auscultation	Dinamap	SpaceLabs	Arterial SBP			Arterial DBP		
				MAX	MIN	MEAN	MIN	MAX	MEAN

Arm circumference: _____

BP cuff size: _____

ABPM #: _____

Arterial line placement: _____

Limb: _____

Type/size cath: _____

Comments: _____

APPENDIX U

SpaceLabs 90202 Monitor Validation Study

Raw Data Sheet -- Cardiology Clinic

SPACELABS 90202 MONITOR VALIDATION STUDY

RAW DATA — CARDIOLOGY CLINIC

Name: _____ Date: _____
Diagnosis: _____ Age: _____
Computer: _____ DOB: _____
Hospital#: _____ Sex: ____ M ____ F

TIME	AUSCULTATION	SpaceLabs BP / HR	
		/	pre-exercise
		/	pre-exercise
		/	pre-exercise
		/	post-exercise
		/	post-exercise
		/	post-exercise

Arm circumference: _____

BP cuff size: _____

ABPM #: _____

Limb: _____

Comments: _____