EFFECT OF ANTHROPOMETRIC FACTORS ON THE REPRODUCIBILITY OF DOPPLER ECHOCARDIOGRAPHIC MEASUREMENTS DURING STATIONARY BICYCLE EXERCISE IN HEALTHY MALES

by

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(ABSTRACT)

The effect of selected anthropometric indices on the reproducibility of continuous wave (CW) Doppler echocardiographic recordings in exercise were studied in 42 healthy males between 18 and 43 years of age. Each subject was measured and rank ordered in reference to four anthropometric indices: sum of 3 skinfolds (SK); chest girth-waist girth ratio (CW); biacromial width-chest depth ratio (WD); and peak exercise ventilation-forced vital capacity ratio (VV). Each subject then performed two maximal bicycle exercise tolerance tests on nonconsecutive days wherein the CW Doppler variables of peak acceleration (pKA), peak velocity (pKV) and stroke velocity integral (SVI) were measured along with heart rate (HR), blood pressure (BP) and respiratory gas analysis data including oxygen consumption ($\dot{V}O_2$). Statistical analyses were then conducted to determine if subject groups with high vs. low values on any anthropometric index differentiated with regard to test-retest reliability between bicycle exercise test trials. Statistical differences were noted between the high and low groups for each index at the .05 alpha level. Pearson's Product Moment correlational analyses revealed that across all subjects the

highest test-retest reliability occurred during the moderate intensity of exercise. The average test-retest correlation coefficients for the high and low groups within each index are as follows: SK_H = .52, SK_L = 62, CW_H = .64, CW_L = .60, WD_H = 62, WD_L = 58, VV_H = 61, VV_L = .67. Inspection of test-retest correlations between the high vs. low groups for the anthropometric indicies revealed a trend in the skinfold index. For each dependent measure at all levels of exercise intensity, the low group exhibited higher correlation coefficients than the high group except for pKA at the peak level of exercise. The other three indicies exhibited no such trends. It was concluded that since the overall correlation coefficients (average = .65) were within the ranges of those computed for HR, BP and $\dot{V}O_2$ (average = .50) the test-retest reliability with the CW Doppler was acceptable; but only during moderate levels of exercise. It was also determined from the correlation coefficients generated by the skinfold index data that measures obtained on lean individuals may be mroe reproducible than measures obtained from obese individuals (See Table 2).

DEDICATION

This Thesis is dedicated to my parents, , whose steadfast love, patience and encouragement gave me the inspiration, opportunity and confidence to pursue my goals.

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The following people helped to make possible the completion of this thesis document and deserve recognition and thanks.

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Next, I would like to extend a special thanks to my friend and research associate , co-inventor of the famous exertional end-point known as the "PJP".

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Many thanks to all of the subjects who devoted so much of their time and effort to this study.

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Chapter I

INTRODUCTION

Over the past 100 years America has gone from an agricultural to an industrial to a technological society. In response to these transformations Americans have made drastic lifestyle modifications. As a society we are far more sedentary than we were 100 years ago. We eat highly processed and preserved food stuffs. Reportedly, we are suffering from more emotional disorders. Perhaps most importantly our daily routines are far more structured resulting in the aforementioned changes.

Physiologically, and perhaps mentally, we have not been able to adapt at a rate equal to our self imposed lifestyle modifications. As a result, the incidence of chronic illnesses such as coronary artery disease and cancer have increased. Due to the prevalence and implications of such chronic diseases, efforts have been made to develop preventive lifestyle strategies, treatments, and effective diagnostic procedures to eliminate them.

There are numerous parameters of cardiac function that can be measured utilizing various techniques, to determine cardiovascular status. The assessment of left ventricular function (LVF) during exercise is considered one of the most important factors in formulating a prognosis after acute myocardial infarction (Mehta, Bennett, Dawkins, Ward, & Mannering, 1986). Traditional modes of assessment such as thermodilution, nuclear imaging procedures, contrast angiography, and electromagnetic blood flow probes are costly and invasive procedures that require highly skilled technicians and generate a great deal of patient stress (Wallmeyer, Wann, Sager, Kalbfleisch, & Klopfenstein, 1986).

An alternative mode of assessment, echocardiography, has been used sparingly in the medical field for the past 30 years (Kisslo, Adams, & Mark, 1986). Until recently data from echocardiographic devices was generated in an auditory or graphic form which made interpretation of Doppler echocardiographic devices subjective and difficult (Kisslo et al., 1986). Advances in technology however, have made Doppler echocardiography a feasible mode of assessment due to the capability to generate data in digital form (Kisslo et al., 1986).

Statement of the Problem

Although the clinical usefulness of Doppler echocardiography seems quite promising, some potential problems with the technique have been identified. Sabbah et al. (1986) has indicated that accurate data are difficult to collect in obese individuals. Furthermore, Quinton Industries also suggested in their EXERDOP operator's manual that accurate data may be difficult to collect on individuals with mesomorphic body structures. Quinton also has indicated that high respiratory rates and volumes in exercise may increase measurement difficulty (Quinton Industries, 1986). Also Garden et al. (1986) suggested that older subjects, due to advanced arteriosclerosis and loss of elasticity in arteries may yield inaccurate blood flow estimations with a Doppler echocardiographic device. To date, there is a lack of sufficient research investigating the reliability of the stand alone CW Doppler mode of echocardiographic devices.

Specifically, more research needs to be conducted addressing the day-to-day reliability present during various exercise intensities. The effects that various morphological characteristics have on day-to-day variability also need to be investigated.

In an attempt to address some of these potential effects the investigator of this study has selected four indices of morphology and attempted to determine their influence on the reproducibility of Doppler derived indicators of blood flow in during different levels of exercise.

Primary Research Question

The following research question was addressed in this study:

Do specified anthropometric characteristics affect test-retest reliability of Doppler echocardiographic derived measures of left ventricular function during low, medium and peak levels of exercise.

Significance of the Study

This study is designed to examine the effect that various anthropometric factors have on the day-to-day reliability of Doppler echocardiographic measures. This information would be of great importance and assistance to clinicians and researchers.

The results of this study may yield insight regarding when data collection is most feasible, in addition to the role that extraneous body motion, elevated respiratory volumes, and morphological patient characteristics play during exercise testing.

Delimitations

The investigator imposed the following delimitations:

1. The sample size was limited to 42 apparently healthy male volunteers between 18-43 years of age.
2. Subjects were selected on the basis of their physical characteristics.
3. The sum of chest, umbilical and thigh skinfolds served as an index of subcutaneous body fat.
4. Exercise performance capabilities were determined by the measurement of $\dot{V}O_2max$.
5. The dependent measures were limited to the Doppler derived variables of peak acceleration, peak velocity and stroke velocity integral.
6. The experimental task consisted of a maximal graded bicycle exercise test.

Limitations

The following limitations affect the generalizability of the findings:

1. The results of this study are applicable only to populations of similar fitness levels, age, and sex as the population utilized in this study for the subjects were relatively homogeneous in relation to these factors.
2. Subject selection occurred in a non-random fashion.
3. Body fat was estimated utilizing skinfold measurement and regression equations; it was not measured directly.
4. $\dot{V}O_2$, not actual performance in terms of mechanical work performed was utilized to establish the 3 levels of exercise.
5. The results of this study only reflect the reproducibility of the Doppler derived variables measured.
6. The results of this study may only be applicable to exercise testing in the cycling mode.

Basic Assumptions

The following basic assumptions were made:

1. That the subjects performed to their maximal physical capabilities during all performance related testing procedures.
2. That the subjects followed all instructions regarding pre-test behaviors, e.g., eating, rest, which might have spuriously affected test results.

3. That the protocol utilized for the bicycle exercise testing is a valid, reliable and sensitive measure of maximal oxygen consumption ($\dot{V}O_2max$).
4. That the anthropometric characteristics measured during this study would not change significantly from pretest to post-test.
5. That the subjects were free from cardiac stenotic or valvular disease which might create abnormal aortic blood flow.
6. That the performance of the EXERDOP unit did not vary day-to-day so as to contribute to error variance of the Doppler responses.
7. That the technicians were adequately trained to perform the data collection procedures accurately and reliably.

Definition of Pertinent Terms

Continuous Wave Doppler (CW) - a Doppler echocardiographic device in which a dual crystal transducer simultaneously transmits and receives a continuous ultrasound beam; changes in beam reflection characteristics arising from disruption by flowing red blood cells provides the basis for flow quantification.

Echocardiography - a diagnostic procedure that utilizes ultrasound to visualize the heart in a noninvasive manner (Feigenbaum, 1972).

Ejection Fraction (EF) - the percentage of the end-diastolic volume that is pumped from the left ventricle (Brooks & Fahey, 1984).

EXERDOP - a stand-alone continuous wave Doppler echocardiographic system designed by Quinton Industries for use during graded exercise testing.

Peak Blood Flow Acceleration (pkA) - the maximum change in blood flow velocity per unit of time, expressed in m/sec/sec.

Peak Blood Flow Velocity (pkV) - the maximum blood flow rate during systole, expressed in m/sec.

Stroke Velocity Integral (SVI) - the area under the curve of a plot of blood flow velocity vs. time expressed in cm. It represents the distance blood travels during the time of velocity measurement for a single systolic ejection.

Suprasternal Notch - the fossa above the superior medial aspect of the manubrium.

Chapter II

REVIEW OF THE LITERATURE

The quantitative evaluation of left ventricular function (LVF) is of great value in assessing cardiovascular status in health and disease. This chapter contains a review of pertinent literature related to the assessment of LVF through the use of Doppler echocardiography. The topics addressed are entitled 1) Basic Description of Doppler Echocardiography, 2) Development of Doppler Echocardiography, 3) Continuous wave vs. Pulsed wave Doppler Echocardiography, 4) Anthropometry, 5) Assessment of Body Composition, and 6) Pertinent Pulmonary and Respiratory Parameters.

Basic Description of Doppler Echocardiography

Doppler echocardiography operates under the premise of the "Doppler effect." In simplistic terms, the Doppler effect asserts that the frequency of a wave source is relative to a receiver depending on the motion of each. Frequency is expressed in units of Hertz. One Hert equals one cycle per second. Doppler ultrasound devices operate in frequencies expressed in mega Hertz. One mega Hert equals one million Hertz (Kisslo, et al., 1986).

There are several different types of echocardiographic devices now utilized in the medical field including M-mode, two dimensional and Doppler echocardiographic devices. M-mode echocardiography is a form of imaging echocardiography that displays in a single dimension known as an "ice pick" view (Harrigan & Lee, 1985). This technique is utilized to examine the motion pattern of structures. This technique is also called time motion scanning (Kleid & Arvan, 1978).

Two-dimensional echocardiography, also known as cross-sectional echocardiography, is a form of imaging echocardiography that displays in two dimensions (Harrigan & Lee, 1985). This technique is utilized to produce two-dimensional images of internal structures, usually the heart (Harrigan & Lee, 1985).

Different types of echocardiographic devices can be utilized in combined fashion known as add-on and duplex systems (Kisslo, et al., 1986). The continuous wave Doppler echocardiographic device utilized in this study is called a "stand alone" system for it is not utilized in conjunction with any other echocardiographic device.

Utilizing Doppler echocardiography an ultrasound beam is transmitted through what is termed a "window" which is an area on the surface of the body that permits the collection of data from a certain internal structure (Kisslo et al., 1986). The two most commonly used windows are the apical window on the anterior surface of the torso used to assess blood flow in the myocardial chambers, and the suprasternal notch used to assess blood flow in the aorta.

A transmitted ultrasound beam is reflected by red blood cells that if moving will cause a change in frequency in the returning beam known as a Doppler shift. The magnitude of the shift is directly related to the velocity of the blood cells and will be positive if the cells are moving toward the transmitted ultrasound beam and negative if moving away from it (Kisslo, et al., 1986).

The angle of the transmitted ultrasound beam is of paramount importance in collecting accurate data. It must be aligned as closely as possible to the flow of blood being measured (see Figure 1). Gardin (1986) noted that deviations in angle are a primary source of measurement error when utilizing Doppler echocardiography.

Under normal conditions, the flow of blood through the heart and aorta is predominantly laminar but in diseased states it may be turbulent. If blood is flowing in a laminar fashion all cells are moving in the same direction at approximately the same velocity. If turbulent flow is present, blood cells are moving in many directions at different velocities.

Several characteristics of Doppler echocardiography make it a valuable tool in assessing cardiovascular status. Bennett, Barklay, Davis, Mannering, & Nawzer (1984) described the Doppler as possessing the following characteristics: it is relatively inexpensive; noninvasive; does not require highly skilled personnel; produces little patient stress; provides instantaneous results; and is well suited for serial testing (3). Kislo (1986), Halfdan, Myhre, Amlic, Furfang, & Larson (1986); Huntsman, et al., and Bennett (1984) all determined Doppler derived data to correlate highly with results generated by

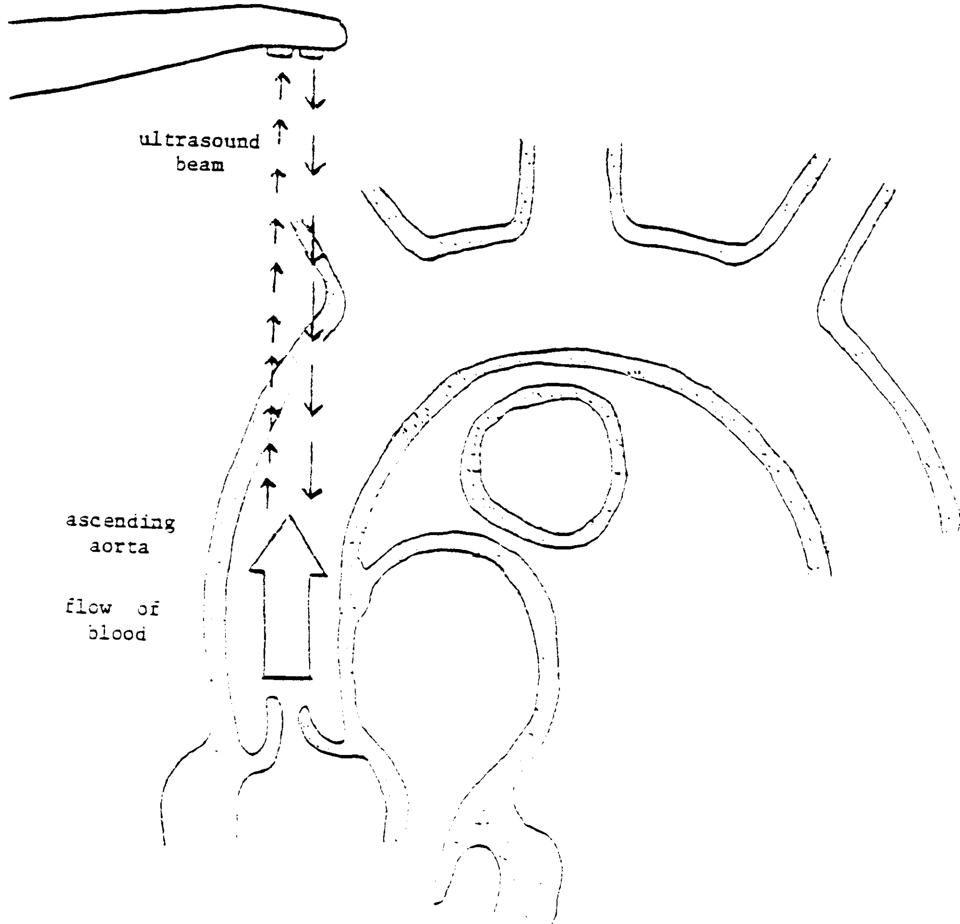

Fig. 1. Representation of the proper alignment of the ultrasound beam to the flow of blood.

thermodilution. Daley, Sagar and Wann (1985) and Sabbah et al. (1986) found that Doppler responses in animal models correlated highly with data derived from electromagnetic flow sensors.

Development of Doppler Echocardiography

The Doppler Effect was first described by Johann Christian Doppler in 1842 in a presentation before the Royal Bohemian Society of Learning. In this presentation he postulated that certain properties of wave phenomena depend on the relative motion of the wave source and receiver (Halliday & Resnick, 1981).

In the early 1900's interest in the application of the theoretical aspects of what had become known as the "Doppler Effect" was rekindled due to the sinking of the Titanic by an iceburg and the advent of submarine warfare. The objective was to develop the technology to detect objects underwater. As a result, sonar was developed. Radar which utilizes radio waves to detect flying objects was developed between the two world wars for similar purposes (Kisslo, et al., 1986).

Following WWII interest in ultrasound generation extended into the medical field. In 1954, Elder and Hertz described the first M-mode echocardiographic system for imaging cardiac structures.

In a paper by Rushmer published in 1964, it was stated that knowledge of maximum cardiac output ($\dot{Q}$) would be of great interest in evaluating cardiac reserve. In this study, Rushmer investigated blood flow characteristics during left and right ventricular ejection utilizing surgically implanted flowmeters in the aorta. Specifically he investigated what he termed initial ventricular impulse which he defined as the product of contractile force of the myocardium and the time interval during systole (Rushmer, 1964). In 1967, Flaherty et al., reported on the first real-time cardiac scanner (Spencer, 1986). In a study published in 1974, Reid, Davis, Ricketts, & Spencer used catheter mounted transducers to measure Doppler flow parameters (Goldberg, Allen, Marx, & Flinn, 1985). Advances in microcircutry and related technology over the past decade have generated rapid modifications of echocardiographic devices thus enhancing their capabilities and applications as prognostic tools.

Continuous Wave vs. Pulsed Wave Doppler Echocardiography

Two types of Doppler echocardiographic devices can be utilized to assess LVF, continuous wave (CW) and pulsed wave (PW). Their operation is based on the same theoretical principles but they each have different transducer designs, operating features, signal processing procedures and, in a specific sense, yield different information (Kisslo, 1986).

Pulsed wave Doppler devices utilize a single crystal transducer functioning alternately as a transmitter and a receiver. The ultrasound beam emitted by the transducer is pulsitile. The advantages of PW Doppler systems are that they can be programmed to sample "selectively" at a specific depth, known as the sample volume, along the ultrasound beam. This process known as range gating is accomplished through the use of a timing mechanism that only samples the returning Doppler shift data from a given region and ignores the rest. Two dimensional imaging echocardiography can be conducted alternatively with the Doppler system providing a visual display for guidance (Kisslo et al., 1986).

The disadvantage of PW Doppler systems are their inability to accurately measure high blood flow patterns such as those found in valvular disease and aortic stenosis. This results in aliasing (error in display of Doppler variables) which is represented on a spectral trace as a cut-off with the remainder of the display in the opposite channel. The Nyquist Limit is a quantitative (numerical) value that defines when aliasing will occur utilizing PD systems. It is determined by dividing the number of pulses per second, known as the pulse repetition frequency, by two. If the Nyquist limit is exceeded aliasing will occur (Kisslo et al., 1986).

Continuous wave Doppler devices utilize a dual crystal transducer. One crystal continuously emits ultrasound waves while the other continuously receives them.

The advantage of CW Doppler devices is their ability to accurately measure abnormally high blood velocities such as those found in disease states. The disadvantages of these devices are their lack of depth discrimination (selectivity) and their incompatibility with two dimensional echocardiographic devices. CW Doppler systems measure Doppler shift data throughout the path of the ultrasound beam which does not allow time for collection of anatomical information. These characteristics could result in the collection of Doppler shift data in multiple heart chambers or blood vessels simultaneously if they lie in the path of the ultrasound beam (Kisslo, 1986).

In considering the advantages and disadvantages of each Doppler system, their applications differ. PW Doppler is indicated if the flow data within a specific location of an anatomical structure is desired. CW Doppler is indicated when accurate measurement of elevated flow patterns are desired (Kisslo, 1986).

Anthropometry

In an attempt to describe the physical characteristics of the human body, the study of anthropometry was developed. Many different techniques have been developed to measure body shape. Kroemer, Kroemer, & Kroemer - Elbert (1986) have described several examples including the Morant technique, the shadow technique, and the use of templates, multiple probes, casting, photography and holography. The National Aeronautics and Space Administration (NASA) has also described several approaches still in the developmental stages including andrometry, stereophotogrammetery, and stereometry (NASA, 1978). Perhaps the simplest technique is direct measurement of the human body with an anthropometer to measure linear dimensions, a beam caliper to measure breadths, a spreading caliper to measure depths, and a steel tape to measure circumferences (NASA, 1978).

Utilizing the measurement techniques described, many investigators have developed classification systems to quantify body shape. Perhaps the most widely recognized system is somatotyping, in which the body is classified on a continuous scale of 1 to 7 in three distinct but related categories. The categories are endomorphy, mesomorphy, and ectomorphy. Endomorphy relates to the predominance of soft roundness throughout the body. Mesomorphy relates to the degree of muscularity. Ectomorphy relates to the predominance of linearity and fragility. The classifications were developed by Sheldon and are based on 18 anthropometric indices. One of which is the Ponderal index which is a subject's height divided by the cubed root of his or her weight. Other classification systems include Viola's morphological index, the Cephalic index and Kretschmer's index (Sheldon, 1963).

Body Composition Analysis

Another way to describe the physical characteristics of the human body is through body composition assessment. Essentially the human body is composed of muscle, bone, blood, bodily fluids, connective tissue, flesh and fat. Another perspective is subclassifying body composition into fat mass and lean mass components.

Many techniques have been developed to predict these components quantitatively; the most widely used techniques include skinfold measurement, hydrostatic weighing, and a variety of anthropometric measurements. Most recently, Segal, Gatin, Preston, Wang, & Van Itallie (1985) and Conway, Norris, and Bodwell (1984) conducted research utilizing bioelectrical impedence analysis. Many clinical techniques have also been developed and investigated. Lohman investigated the validity of densiometry, hydrometry and nuclear magnetic resonance (Lohman, 1984). Ashwell, Cole, & Dixon (1985) and Borkan & Hults (1983) investigated computed body tomography. Conway, Norris, & Bodwell (1984) compared the deuterium oxide dilution technique with infrared interactance.

All clinical body composition assessment techniques have two common characteristics, they are expensive and they require sophisticated equipment. Many researchers, including Jackson and Pollock (1978) and Sinning et al., (1984) have concluded that data derived utilizing the appropriate prediction equations in conjunction with skinfold measurement techniques yields very high correlations with results obtained by hydrostatic weighing which is considered the "Gold Standard" of body composition analysis (Pollock & Jackson, 1978; Sinning et al., 1984).

Several potential sources of measurement error associated with the skinfold measurement technique have been identified by Pollock and Jackson (1984). These include improperly calibrated calipers, use of different calipers, multiple data collectors, lack of investigator experience with the technique, inconsistency of manual technique, and improper site location and angulation (Pollock & Jackson, 1984). NASA (1978) suggested that subject hydration level could also effect measurement validity and reliability.

Pertinent Pulmonary and Respiratory Parameters

Several investigators have indicated that increased respiratory volumes and frequencies may contribute to measurement variability when utilizing echocardiography (Gardin et al., 1987; Quinton Industries, 1986; and Shaw, Johnson, Varies, & Greene, 1985). The respiratory parameters of interest are minute ventilation ($\dot{V}_E$) during exercise, breathing frequency (f) during exercise and vital capacity (VC). Ruppel defines V_E as the total volume of gas expired per minute by the exercising subject. This parameter is usually measured utilizing a flow sensing device such as a pneumotachometer. Relating the V_E max achieved during exercise to static measures of ventilatory function may yield indices of the role of ventilatory limitations to exercise (Ruppel, 1986).

Respiratory rate is the number of breaths per unit of time. The rate can be determined by counting the chest movements or the excursions of a V_E measuring device (Ruppel, 1986).

Ruppel defines vital capacity as the largest volume measured on a complete expiration after a maximal inspiration. This parameter is measured using a spirometer. Several variables have been determined to affect VC values including height, age, sex, body position, level of motivation, race and ethnic origin, and chronic or acute pulmonary and respiratory disease (Ruppel, 1986).

It has been proposed that large ventilatory rates and volumes may effect the accuracy and reproducibility of Doppler echocardiographic data collected during exercise (Quinton Industries, 1986; Gardin et al., 1984).

Summary

Doppler echocardiography operates under the principle of the Doppler Effect. The Doppler Effect was first described by Johann Christian Doppler in 1842. There are basically two types of Doppler echocardiographic systems, continuous wave and pulsed wave (Kisslo, 1986). The study of anthropometry was developed in an attempt to study the physical characteristics of the human body (Kroemer et al., 1986). A related procedure to anthropometry is the assessment of body composition. The simplest yet clinically acceptable method of body composition assessment is the measurement of subcutaneous body fat utilizing skinfold calipers. The volume of structures inside the body as well as outside can be measured. One such structure commonly measured for research purposes is the lung. Two commonly measured lung volumes are resting vital capacity and minute ventilation during maximal exercise. The purpose of this study is to investigate the effects of subcutaneous body fat level, body torso shape, and exercise respiration parameters on the reproducibility of Doppler indicators of ventricular function during graded bicycle exercise testing of healthy adult males.

Chapter III

Journal Manuscript

Effect of Anthropometric Factors on the Reproducibility of Doppler Echocardiographic Measurements During Stationary Bicycle Exercise in Healthy Males

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(abbreviated title for running head)
Anthropometry and Doppler Reproducibility

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ABSTRACT

EFFECT OF ANTHROPOMETRIC FACTORS ON THE REPRODUCIBILITY OF DOPPLER ECHOCARDIOGRAPHIC MEASUREMENTS DURING STATIONARY BICYCLE EXERCISE IN HEALTHY MALES

by

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The effect of selected anthropometric indices on the reproducibility of continuous wave (CW) Doppler echocardiographic recordings in exercise were studied in 42 healthy males between 18 and 43 years of age. Each subject was measured and rank ordered in reference to four anthropometric indices: sum of 3 skinfolds (SK); chest girth-waist girth ratio (CW); biacromial width-chest depth ratio (WD); and peak exercise ventilation-forced vital capacity ratio (VV). Each subject then performed two maximal bicycle exercise tolerance tests on nonconsecutive days wherein the CW Doppler variables of peak acceleration (pKA), peak velocity (pKV) and stroke velocity integral (SVI) were measured along with heart rate (HR), blood pressure (BP) and respiratory gas analysis data including oxygen consumption ($\dot{V}O_2$). Statistical analyses were then conducted to determine if subject groups with high vs. low values on any anthropometric index differentiated with regard to test-retest reliability between bicycle exercise test trials. Statistical differences were noted between the high and low groups for each index at the .05 alpha level. Pearson's Product Moment correlational analyses revealed that across all subjects the

highest test-retest reliability occurred during the moderate intensity of exercise. The average test-retest correlation coefficients for the high and low groups within each index are as follows: SK_H = .52, SK_L = .62, CW_H = .64, CW_L = .60, WD_H = 62, WD_L = .58, VV_H = .61, VV_L = .67. Inspection of test-retest correlations between the high vs. low groups for the anthropometric indicies revealed a trend in the skinfold index. For each dependent measure at all levels of exercise intensity, the low group exhibited higher correlation coefficients than the high group except for pKA at the peak level of exercise. The other three indicies exhibited no such trends. It was concluded that since the overall correlation coefficients (average = .65) were within the ranges of those computed for HR, BP and $\dot{V}O_2$ (average = .50) the test-retest reliability with the CW Doppler was acceptable; but only during moderate levels of exercise. It was also determined from the correlation coefficients generated by the skinfold index data that measures obtained on lean individuals may be mroe reproducible than measures obtained from obese individuals (See Table 2).

INTRODUCTION

The assessment of left ventricular function (LVF) during exercise is considered one of the most important factors in formulating a prognosis after acute myocardial infarction (10). Traditionally, LVF has been assessed utilizing methods such as thallium perfusion imaging, and thermaldilution. These methods involve costly, invasive procedures that require highly skilled technicians and place a great deal of stress on the patient (13). Such limitations make wide scale utilization of these testing procedures economically infeasible.

Many of these limitations are overcome by Doppler echocardiography. Bennett et al. (1) described the Doppler as possessing the following characteristics: it is relatively inexpensive; noninvasive; does not require highly skilled personnel; produces little patient stress; provides instantaneous results; and is well suited for serial testing. Doppler echocardiography has been determined to be an accurate indicator of LVF. Bennett et al. (1), Halfdan et al. (5), Huntsman et al. (6), and Khaja et al. (8) all determined Doppler derived data to correlate highly to results generated by thermodilution. Daley, Sugar, and Wann (3) and Sabbah et al. (12) reported that Doppler responses in animal models correlated highly with data derived from electromagnetic flow sensors.

Although the clinical usefulness of Doppler echocardiography seems quite promising, some potential problems with the technique have been identified. Sabbah et al. (12) has indicated that accurate data are difficult to collect in obese individuals. Furthermore, Quinton Industries, a manufacturer of a dedicated exercise continuous wave (CW) Doppler system (EXERDOP) has also suggested that accurate data may be difficult to collect on individuals with mesomorphic body types (11). Futhermore, Quinton Industries also has indicated that high ventilatory flow rates and respiratory frequencies during exercise may increase measurement difficulty. Garden et al. (4) suggested that older subjects, due to advanced arteriosclerosis (calcification of intima) and loss of elasticity in arteries may yield inaccurate blood flow estimations with Doppler devices.

This study represents an attempt to address some of the aforementioned issues. Specifically, four indices of morphology have been defined, and a protocol designed, to determine the influence of these test-retest on reproducibility of CW Doppler indicators of blood flow at different intensities of exercise.

Methodology

Forty-two apparently healthy males between 18 and 43 years of age, selected on a volunteer basis gave their informed consent. Anthropometric data were collected and two multi stage bicycle exercise tolerance tests were administered on non-consecutive days to each subject. The anthropometric data collected were utilized to compute values for four anthropometric indicies. The sum of chest, umbilical and thigh skinfolds comprised the skinfold index (SK). The ratio of chest and waist circumference comprised the chest girth-waist girth index (CW) and was empirically accepted as a simple soft-tissue indicator of ecto-endomorphy. The ratio of biacromial width to chest depth comprised the width-depth ratio index (WD). This index was empirically accepted as an indicator of "deep chestedness" vs. "shallow-chestedness". The ratio of peak exercise ventilation to vital capacity was calculated as an index of maximal ventilatory stress, adjusted for subject differences in body size and was called the ventilation-vital capacity ratio index (V-V). The values obtained for each subject on each index were then rank ordered. For each index, the 15 highest scores represented the group considered high for a given variable, the 15 lowest represented the "low" group. The scores for the 12 mid-range subjects were not utilized.

In each bicycle exercise test heart rate (HR), blood pressure (BP), and respiratory data, including minute ventilation (V_E) and oxygen consumption ($\dot{V}O_2$) were collected at each stage of exercise. The dependent measures of peak acceleration (pKA), peak velocity (pKV), and stroke velocity integral (SVI) were also measured under postural conditions of supine rest, upright rest and at each stage of exercise with a CW Doppler Echocardiographic device, i.e., EXERDOP (Quinton Industries).

Doppler parameters were measured by placing the transducer head of the probe at the suprasternal notch of the subject. The probe was then angulated in response to an auditory que the technician received through stereo headphones. The technician attempted to locate and maintain the position in which the loudest and sharpest auditory signal was generated indicating proper alignment to blood flow in the ascending aorta.

The bicycle test protocol consisted of 3 minute stages with an initial resistance of 50 watts and increasing by 50 watts per stage. Subjects exercised to a point of expressed fatigue or until they could no longer keep the required cadence of 50 rpm. The dependent measures were investigated at three exercise intensities, as previously determined by individual $\dot{V}O_2max$ testing. These stages corresponded to ~33%, ~67% and 100% of $\dot{V}O_2max$. Independent t-tests were performed between the high and low groups for each anthropometric index and for the exercise ventilatory index. This was performend prior to exercise testing to determine if a statistically significant difference existed between the high and low groups within each index.

The EXERDOP responses in the high and low groups for each anthropometric index and the ventilatory index were evaluated for stability reliability (test-retest) at the low, moderate and peak exercise levels utilizing Pearson's product moment correlational analyses.

Results

The means ($\bar{X}$), standard deviations (SD), t values and probabilities of the calculated values of the anthropometric indicies from the Independent t-tests are presented in Table 1.

Insert Table 1 about here.

Each anthropometric index and the ventilatory index comprised statistically significant differences between the high and low group at the .05 level of significance.

Stage Response Comparison

The means, standard devisions and test-retest reproducibility coefficients for pKA, pKV and SVI at each exercise intensity according to the high vs. low group for each anthropometric index and the ventilatory index are presented in Table 2. These correlation coefficients indicate the degree to which the Doppler parameters were reproducible.

Insert Table 2 about here.

The correlation coefficients on all 42 subjects for pKA ranged from .58 to .64, for pKV, .68 to .79, and for SVI, .50 to .69.

To serve as a comparison, the means, standard deviations and correlation coefficients for HR, SBP and $\dot{V}O_2$ are presented in Table 3. These parameters have been determined in prior studies to be reproducible indicators of hemodynamic responses (2).

Insert Table 3 about here.

Insert Figure 1 about here.

The correlation coefficients for HR ranged between .37 and .44, for SBP, .45 - .62, and for $\dot{V}O_2$ .33 - .62. The means, standard deviations and test-retest correlation coefficients of peak acceleration for all anthropometric indicies are prsented in table 4.

Insert Table 4 about here.

Insert Figure 2 about here.

The means, standard deviations and test-retest correlation coefficients of peak velocity for all anthropometric indicies are presented in table 5.

Insert Table 5 about here.

Insert Figure 3 about here.

The means, standard deviations and test-retest correlation coefficients of stroke velocity integral for all anthropometric indicies are presented in table 6.

Insert Table 6 about here.

Insert Figure 4 about here.

The test-retest correlation coefficients for the skinfold index indicate that the low fat group generated more reproducible results than the high fat group.

The correlation coefficients for the chest-waist, width-depth, and ventilatory indicies showed no similar trends to those exhibited by the skinfold index.

Discussion

Each anthropometric index was developed to study morphological and physiological characteristics which have been previously questioned as having potential and reducing the accuracy and reliability of CW Doppler measurements in exercise. Sabbah (12) indicated that data obtained from obese subjects may be less accurate and reliable than data collected from subjects with normal ranges of percent body fat. The skinfold index is an indicator of subcutaneous body fat that was used to investigate this speculation. It should be noted however, that the high fat group as a whole possessed within noral ranges of body fat and can not be considered obese. Test-retest reliability coefficients were higher for the low skinfold group than the high group for each dependent measure at all levels of exercise with the exception of pKA at the peak level. These results indicate that subcutaneous fat and possibly total body fat may be important variables affecting reliability under the existing test conditions. However, subcutaneous body fat level, per se, may not be the cause of the differences between groups, for most individuals have very little subcutaneous body fat in the region of the suprasternal notch. It is speculated by the researcher that intra-organ fat level, however, may be the source of the difference between the two groups due to changes in attenuation of the ultrasound beam.

The chest circumference, waist circumference ratio index (CW) was developed to investigate the notion reported by Quinton Industries that individuals with mesomorphic body builds may exhibit lower stability reliability with exercise Doppler measurements (11). The chest width, depth ratio index (WD) was designed to investigate basically the same question but in contrast to the CW index, focus more precisely on the skeletal proportions of the anterior-superior torso components of somatotype.

Both of these indicies were intended to be indicators of meso-ectomorphy. The CW index was a soft tissue measurement designed for placing subjects on a continuum from nonmuscular to very muscular. Mesomorphic individuals typically have large chest circumferences in relation to that of their waists and the converse is typically true of nonmuscular individuals.

The WD index was designed to discriminate "deep chested" individuals from those having shallow chests. It was thought that the deep chested individuals may yield lower reliability coefficients when tested with the Doppler instrument due to the greater degree of tissue in the upper thoracic region as compared with shallow chested individuals. The degree of mesomorphy and chest depth have been speculated to affect Doppler measurement. Ultrasound waves travel at different velocities through different tissues thus, if one has an excessive degree of muscle (or fat) it may affect the signal transmission to the blood flow stream as well as the reflection of the ultrasound energy returned to the probe sensor. Kraus (9) described the velocity of ultrasound waves through various tissues.

Insert Table 7 about here.

Both of the aforementioned indexes were empiracally developed and, in this study, were not found to cause differential effects upon test-retest reliability. Perhaps more traditional indicies of mesomorphy, such as the ponderal index, should be utilized in future research.

The maximal ventilation, vital capacity ratio index (VV) is somewhat more of a physiological index than the other three. It addresses the assertion suggested by Garden (4) and Quinton Industries (11) that high ventilatory rates and volumes may affect the reliability of Doppler derived measurements. This index was developed to investigate the effects of peak ventilatory flow potential in exercise while controlling for individual differencies in anatomical size of the pulmonary system. Three factors; peak flow rate, minute ventilation ($\dot{V}_E$) and respiratory frequency (f) are possibly relevant pulmonary flow factors to consider in examining such potential effects on Doppler measurements. The VV index utilized $\dot{V}_E$ which is related to f. $\dot{V}_E$ adjusted for anatomical pulmonary system size was not found to be associated with differential effects upon test-retest reliability. Direct measurement of f however, may prove to be associated with variations of test-retest reliability and should be addressed in future research. Although it was not measured in this study, the researcher speculates that increased respiratory rates may cause a decrease in test-retest reliability due to the rapid movements of the respiratory musculature and related structures. These movements may make it more difficult to interogate the ascending aorta.

It is generally accepted that HR, SBP, and $\dot{V}O_2$ are highly reproducible during exercise. However, the range for the correlation coefficients for these variables was rather large. The range of correlation coefficients for pKA, pKV and SVI across all 42 subjects were found to be well within the ranges calculated for HR, SBP and $\dot{V}O_2$. This suggests that under the given conditions the Doppler derived variables were determined to be reproducible to the same extent as determined with physiological variables conventionally measured in clinical exercise tests. However, these correlation coefficients are in fact quite low when judged in the context of clinical and research standards in which correlations of .90 or greater are usually required to be acceptable.

In a previous study (3), results of Doppler measurements were compared to measurements derived through cardiogreen dye indicator dilution and found to be correlated highly. The natural values however, were not reported. Unlike the current study, however, Daley's et al. (3) subjects exercised in a supine position ("kept flat") and were instructed to momentarily hold their breath to eliminate extraneous motion. The absence of extraneous muscle tension and related motion of the interogation site may also explain why test-retest reliability coefficients calculated for passive subjects were reported to be greater than those with subjects of the present study (13).

Of the three levels of exercise investigated, the greatest reproducibility of all dependent measures occurred during the moderate level (see Tables 2 & 3). At the low level the subject's state of arousal/anticipation may have led to varying levels of catacholamines released into the blood stream which could have altered aortic blood flow characteristics secondary to variations in cardiac contractility (2). At the peak level of exercise variations in body movements which may cause motion artifact and motivational state may have affected the test-retest reliability. The effect of differing motivational states on catacholamine release and its effect on hemodynamic responses has been well documented (2). Increased circulating catacholamine in the blood stream is known to cause increased HR and BP. Due to the fact that few of the subjects were regular cyclists, one could expect a possible variation in performance between trials of bicycle exercise tolerance testing. Thus the low correlations determiend for the dependent measures and comparison measures between the two trials may be due to variations in actual performance. Much of the error variance then, can be attributed to the subjects themselves. Other sources of error variance are the technician skill level and variance within the EXERDOP instrument itself. Prior to data collection. the EXERDOP technician practiced using the instrument on exercising subjects at moderate exercise intensities. Thus, it was assumed that the technician was adequately trained. A previous study (7) comparing the EXERDOP to invasive techniques well established for accuracy and reliability have found the instrument to have little inherent error. The mean percentages of valid values accepted by the instrument in this study were similar from test to test but decreased during peak exercise in both tests, perhaps due to the poential sources of error discussed previously.

The research literature addressing the topic of Doppler Echocardiography has suggested that factors such as obesity, degree of muscularity and exercise ventilatory patterns may affect the validity and reliability of pKA, pKV and SVI (4), (11), (12). The results of the current study indicate that subjects with lower levels of subcutaneous body fat yielded higher test-retest correlation coefficients on all dependent variables during all levels of exercise with the exception of pKA during peak exercise as opposed to those with higher levels. No other index used in this study displayed any similar trends.

In conclusion, the results of this study indicate that the Exerdop CW Doppler is a reliable device for measuring specified variables related to LVF in reference to standard hemodynamic variables. However, in reference to clinical and research standards the realiability coefficients were poor. This may have been due to inconsistency in subject performance or technician measurement technique and not necessarily due to inherent variance of the instrument. Highest reproducibility occurred during the moderate exercise intensity for the overall subject population. Of the anthropometric indicies only the skinfold index appeared to be a indicator of changes in reproducibility. Subjects with low levels of subcutaneous body fat levels were found to yield more reproducible test-retest results than those with higher subcutaneous body fat levels.

Table 1. Independent t-test results performed between the high and low groups for each anthropometric index (n = 42).

Index	Low Group		High Group		t	prob
	$\overline{X}$	SD	$\overline{X}$	SD		
SK	29.00	5.50	48.79	16.42	- 6.66	< .01
CW	1.14	0.03	1.27	0.03	-11.22	< .01
WD	1.72	0.08	2.09	0.13	- 9.49	< .01
VV	13.15	3.93	21.58	2.71	- 6.84	< .01

Table 2. Means, Standard Deviations and Test-Retest Correlation Coefficients for Doppler Measures for all Subjects (n = 42)

	Exercise			Intensity		
	Low		Moderate		Peak	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
PKA_1	25.1	10.6	45.6	14.8	49.0	12.9
PKA_2 ($m \bullet sec^{-2}$)	23.0	5.6	45.6	11.8	49.4	11.4
r*	.58		.84		.60	
PKV_1	.90	.18	1.10	.19	1.00	2.5
PKV_2 ($m \bullet sec^{-1}$)	.90	.15	1.11	.17	1.03	.20
r*	.76		.79		.68	
SVI_1	12.3	2.6	10.4	2.5	7.5	2.2
SVI_2 (cm)	12.5	2.7	10.7	2.3	7.7	1.9
r*	.60		.69		.50	

*Correlation coefficients (Parson's r)

Table 3. Means and Standard Deviations and Test-Rest Correlation Coefficients of Comparison Measures for all Subjects (n = 42)

	Exercise Intensity					
	Low		Moderate		Peak	
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
HR_1	99	13	145	25	184	21
HR_2 (bpm)	100	14	148	15	182	11
r*	.37		.44		.44	
SBP_1	144	17	173	21	197	17
SPB_2 (mmHg)	137	15	173	17	195	18
r*	.60		.45		.62	
VO_2-1	15	11	27.4	5	39	6
VO_2-2 $ml \bullet kg^{-1} \bullet min^{-1}$	14	3	28	5	40	7
r*	.60		.33		.61	

*Correlation coefficients (Parson's r)

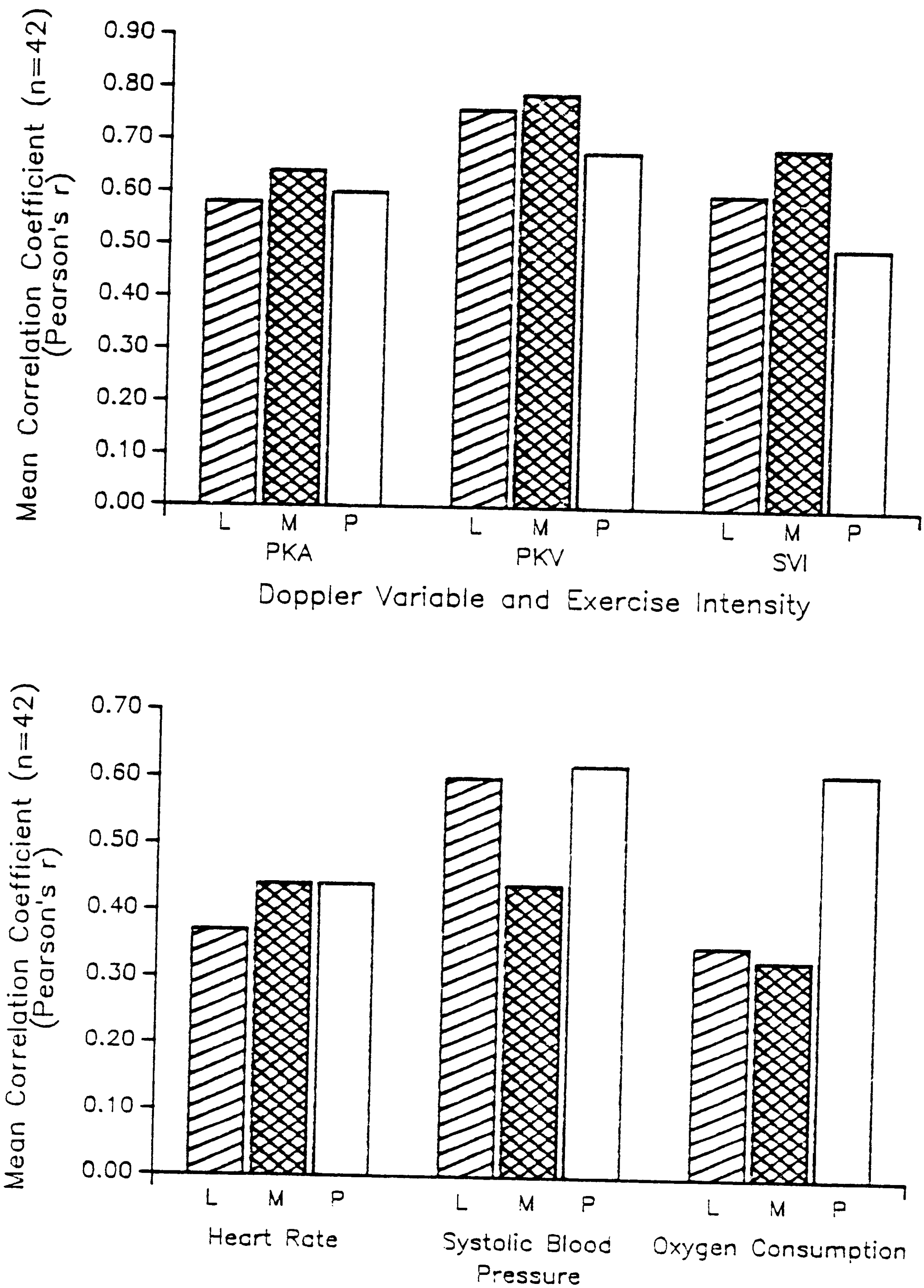
Mean Correlation Coefficient (n=42)
(Pearson's r)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
L M P
PKA
L M P
PKV
L M P
SVI
Doppler Variable and Exercise Intensity
Mean Correlation Coefficient (n=42)
(Pearson's r)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
L M P
Heart Rate
L M P
Systolic Blood Pressure
L M P
Oxygen Consumption

Figure 1.

Table 4. Means, Standard Deviations and Test-Retest Correlation Coefficients of Peak Acceleration for each Anthropometric Index.

Index	Test	High Group (n = 15)						Low Group (n = 15)					
		Low*		Mod*		Peak*		Low*		Mod*		Peak*	
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
Skinfold	1	27.3	12.4	47.7	12.4	49.2	10.7	28.0	10.2	47.4	15.7	40.6	14.5
	2	22.8	5.8	44.6	9.6	49.7	7.6	24.6	6.4	48.1	14.6	42.2	12.2
	r ≠	.45		.42		.55		.72		.66		.36	
Chest-Waist	1	25.5	13.1	45.1	13.6	46.2	13.1	23.4	7.1	44.9	14.6	48.1	10.7
	2	22.9	6.5	45.1	7.7	45.1	8.4	22.2	5.3	41.6	8.7	48.5	8.3
	r ≠	.68		.70		.38		.45		.48		.63	
Width-Depth	1	23.3	9.9	42.3	16.2	42.7	7.4	27.3	13.6	47.3	12.8	50.1	15.1
	2	21.9	5.9	44.3	14.6	49.7	9.1	23.5	6.1	47.4	7.2	46.9	9.7
	r ≠	.89		.68		.30		.36		.76		.65	
Ventilatory	1	32.8	12.5	48.7	14.3	42.3	14.7	19.1	4.5	41.7	13.7	47.7	12.2
	2	25.7	5.6	48.5	14.6	42.3	11.8	21.3	6.1	41.1	9.5	47.4	8.4
	r ≠	.37		.62		.56		.69		.71		.54	

Peak Acceleration values expressed in m•min^{-2}

*Exercise intensity

≠ Correlation coefficients (Pearson's r)

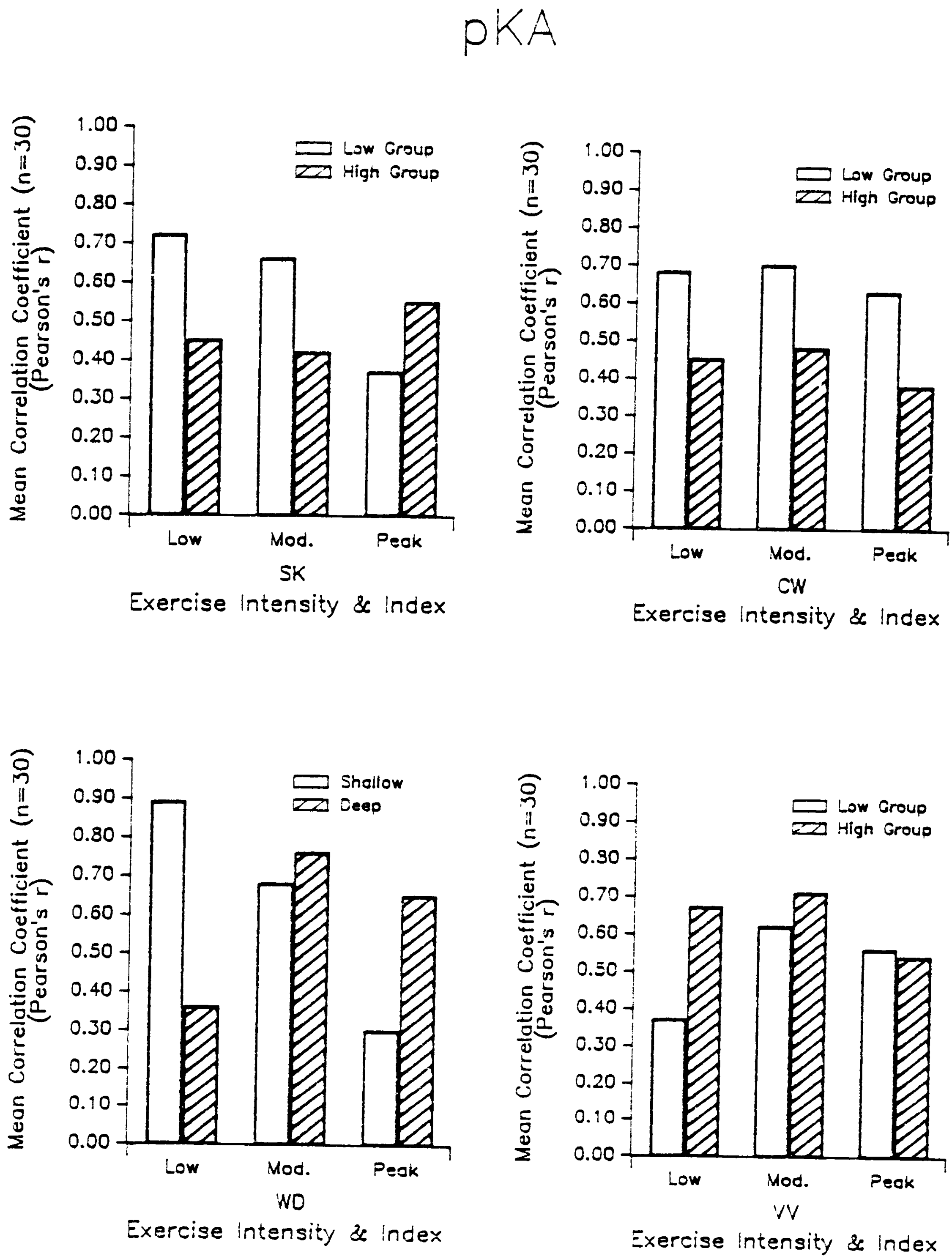
pKA
Mean Correlation Coefficient (n=30) (Pearson's r)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low Group
High Group
Shallow
Deep
Low
Mod.
Peak
SK
CW
WD
VV
Exercise Intensity & Index

Figure 2.

Table 5. Means, Standard Deviations and Test-Retest Correlation Coefficients of Peak Velocity for each Anthropometric Index.

Index	Test	High Group (n = 15)						Low Group (n = 15)					
		Low*		Mod*		Peak*		Low*		Mod*		Peak*	
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
Skinfold	1	.92	.54	1.10	.16	.96	.18	.99	.17	1.20	.19	1.10	.29
	2	.90	.14	1.10	.13	1.00	.18	.93	.18	1.20	.19	1.10	.20
	r=	.69		.70		.47		.80		.70		.57	
Chest-Waist	1	.86	.17	1.11	.20	.97	.29	.90	.16	1.06	.17	.94	.18
	2	.88	.14	1.12	.18	.96	.19	.87	.12	1.05	.08	.98	.16
	r=	.76		.87		.64		.73		.56		.63	
Width-Depth	1	.87	.19	1.10	.19	.91	.14	.87	.18	1.04	.15	.97	.27
	2	.85	.16	1.10	.15	1.03	.16	.87	.12	1.07	.14	.97	.17
	r=	.76		.66		.37		.65		.85		.71	
Ventilatory	1	1.02	.13	1.11	.17	1.04	.26	.79	.15	1.07	.20	1.00	.28
	2	.95	.16	1.16	.21	1.03	.22	.85	.14	1.08	.14	1.06	.17
	r=	.65		.76		.72		.77		.91		.65	

Peak Acceleration values expressed in m•min^{-2}

*Exercise intensity

= Correlation coefficients (Pearson's r) pKV

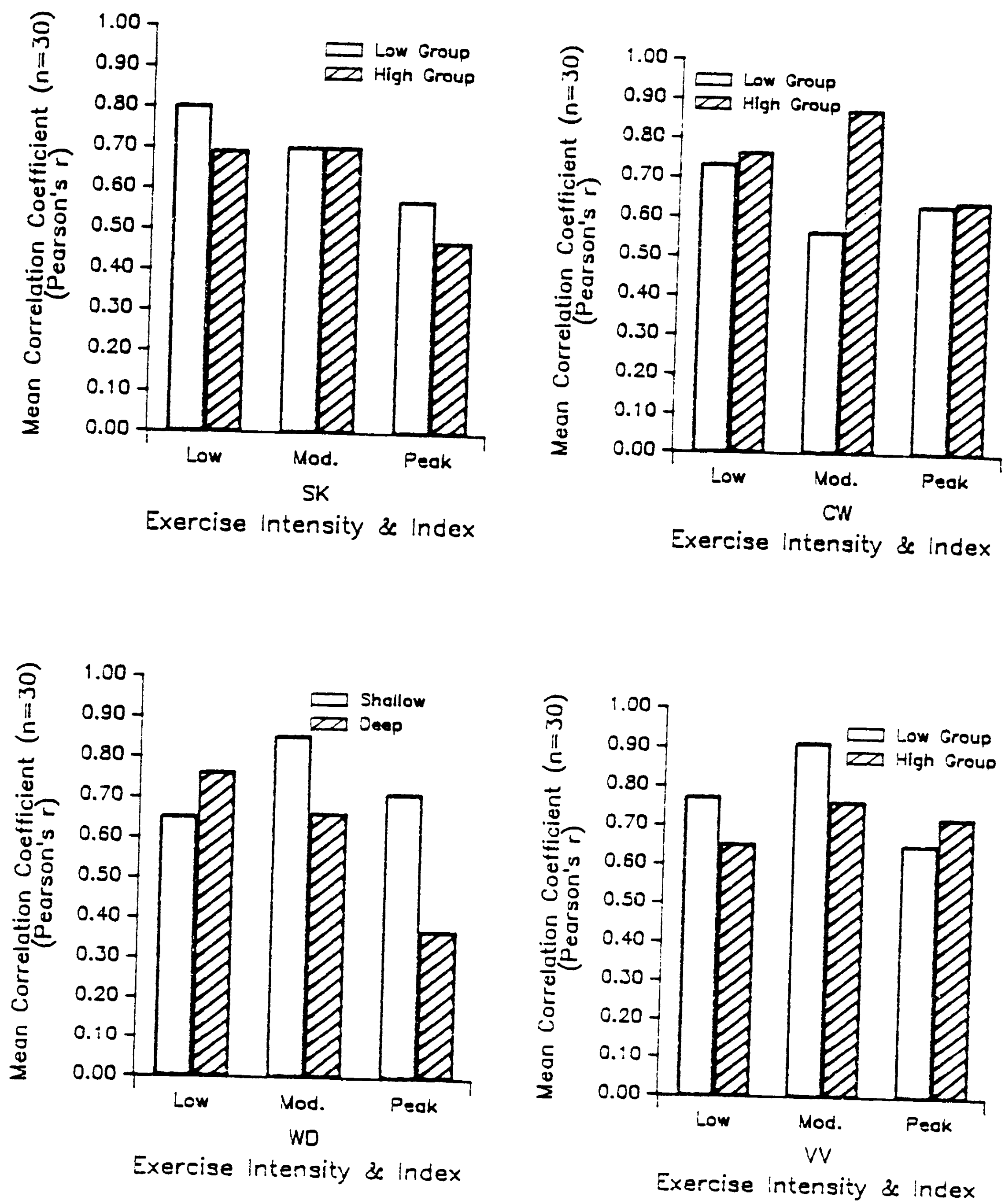
Mean Correlation Coefficient (n=30) (Pearson's r)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low Group
High Group
Shallow
Deep
Low
Mod.
Peak
SK
CW
WD
VV
Exercise Intensity & Index

Figure 3.

Table 6. Means, Standard Deviations and Correlation Coefficients of Velocity Integral for each Anthropometric Index.

Index	Test	High Group (n = 15)						Low Group (n = 15)					
		Low*		Mod*		Peak*		Low*		Mod*		Peak*	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Skinfold	1	12.5	2.2	9.9	2.0	6.8	1.5	12.6	2.7	10.6	2.7	8.1	2.4
	2	13.4	2.7	10.9	2.5	7.4	1.7	11.7	2.9	10.7	2.7	7.9	2.0
	r ≠	.57		.58		.21		.63		.80		.34	
Chest-Waist	1	11.2	3.1	10.3	2.1	7.4	2.4	12.6	2.3	10.1	2.3	7.1	1.9
	2	12.3	2.6	10.5	2.1	7.4	2.8	12.6	2.5	10.5	2.5	7.5	1.9
	r ≠	.63		.58		.56		.73		.54		.61	
Width-Depth	1	11.4	2.5	9.9	1.9	7.1	1.6	12.2	2.1	9.6	2.5	6.8	2.3
	2	11.4	3.0	10.2	1.8	7.8	1.8	13.0	2.5	10.1	2.8	7.0	1.6
	r ≠	.78		.76		.39		.38		.53		.35	
Ventilatory	1	13.4	2.5	10.5	2.8	7.6	2.1	11.1	2.6	10.0	2.3	7.7	2.7
	2	12.6	3.2	10.7	3.0	7.4	2.0	12.1	2.7	10.7	1.7	8.4	1.9
	r ≠	.52		.69		.62		.74		.66		.37	

Peak Acceleration values expressed in $m \bullet min^{-2}$

*Exercise intensity

≠ Correlation coefficients (Pearson's r)

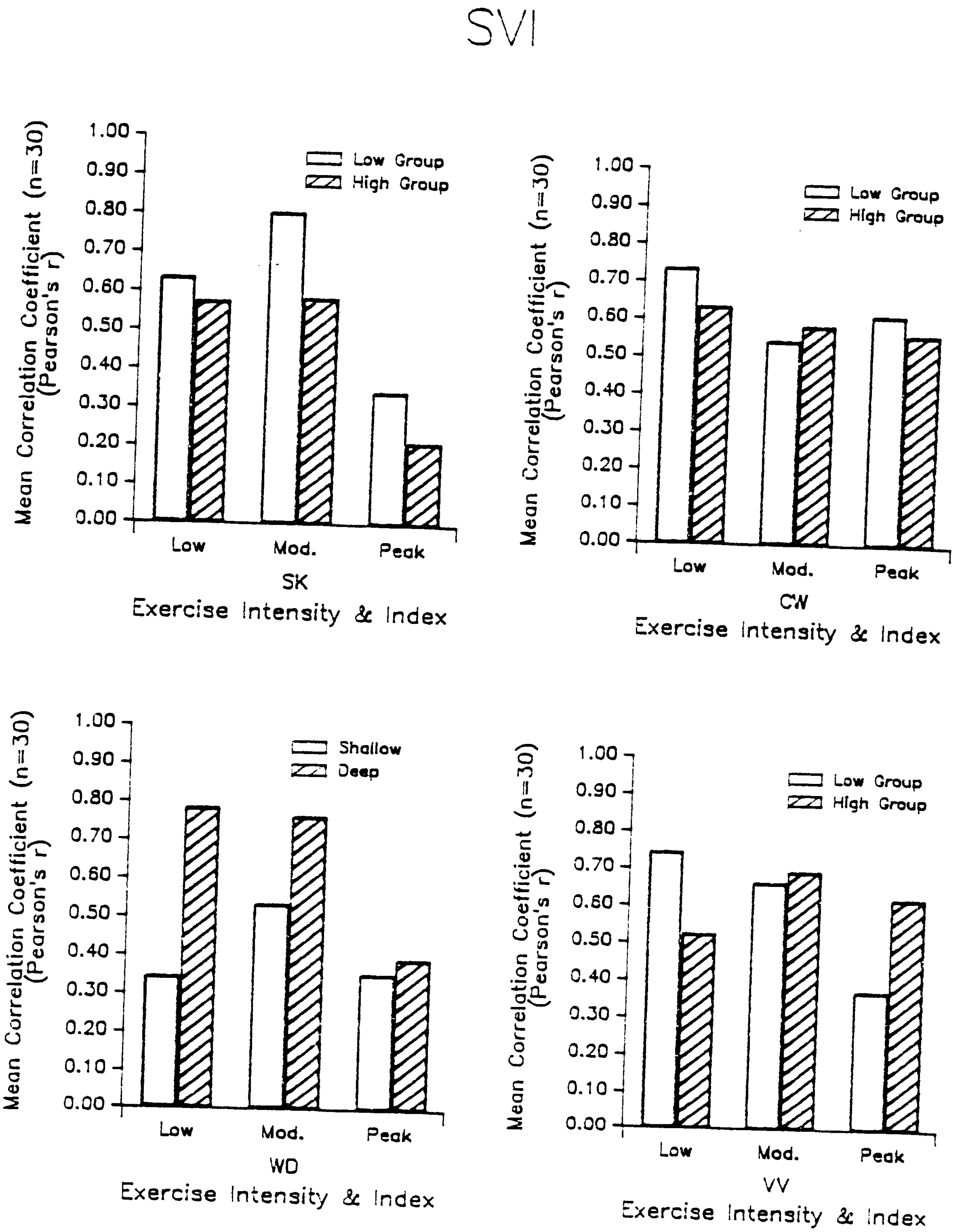
SVI
Mean Correlation Coefficient (n=30) (Pearson's r)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Low Group
High Group
Low
Mod.
Peak
SK
Exercise Intensity & Index
CW
Exercise Intensity & Index
Shallow
Deep
WD
Exercise Intensity & Index
VV
Exercise Intensity & Index

Figure 4.

LIST OF FIGURES

4 Correlation Coefficients (Pearson's r) for Stroke Velocity Integral at the Low, Moderate (Mod.), and Peak Level of Exercise for Each Index. Skinfold Index (SK), Chest Circumference-Waist Circumference Ratio Index (CW), Biacromial Width-Chest Depth Ratio Index (WD), Peak Ventilation-Vital Capacity Ratio Index (VV). Capacity Ratio Index (VV)

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Chapter IV

SUMMARY AND CONCLUSIONS

The purpose of this study was to investigate the effect of anthropometric indices on the test-retest reproducibility of Doppler echocardiographic measurements of aortic blood flow during exercise. Anthropometric data and Doppler derived data were collected on 42 subjects. Values obtained during anthropometric data collection were utilized to develop four indicies. The skinfold index comprised the sum of chest, umbilical and thigh skinfolds. It served as an indicator of subcultaneous and total body fat. The chest circumference, waist circumference ratio index was calculated by dividing the subjects chest circumference by his waist circumference. It served as an indicator of meso-endomorphy. The chest width, depth ratio index was determined by dividing the depth of the chest by its biacromial width. It served as an indicator of "deep chestedness" vs. "shallow chestedness". The peak exercise ventilation, vital capacity index was calculated by dividing a subject's peak minute ventilation by his vital capacity. It was designed to serve as an indicator of the degree of motion of the structures of the pulmonary system and respiratory stress. Subjects were rank ordered into high and low groups in reference to each index.

Two bicycle exercise tolerance tests were administered on non-consecutive days during which heart rate, blood pressure, respiratory data, and the dependent measures of peak acceleration, peak velocity and stroke velocity integral were measured utilizing a "stand alone" continuous wave Doppler (EXPERDOP) developed by Quinton Industries, Seattle, WA. The protocol for the bicycle tests consisted of 3 minute step-wise stages with an initial resistance of 50 Watts and a 50 Watt increase per stage thereafter. Subjects exercised till fatigue or they could no longer maintain the 50 rpm auditory cadence produced by an electronic metronome.

Doppler measures were collected during the final minute of each stage utilizing a hand held probe with the transducer head placed at the suprasternal notch. The probe was angulated in response to auditory feedback the technician received from the instrument through stereo headphones. It was assumed that the sharpest and loudest auditory signals occurred when the transducer head was most precisely aligned with the flow of blood through the ascending aorta.

A Pearson's Product Moment correlational analysis was conducted on each of the dependent measures at three exercise intensities for the high and low groups differentiated by each anthropometric index between bicycle exercise test trials to determine stability reliability. Pearson's Product Moment correlational analyses were also conducted for HR, SBP and $\dot{V}O_2$ to serve as comparison variables.

The results of the study indicated that for all subjects collectively the most reproducible Doppler derived data were collected during the moderate exercise level. The results also suggest that the degree of subcutaneous body fat can affect the reliability of Doppler data collection. Leaner subjects appeared to yield more reproducible results than those with more body fat. Comparison of the dependent measures with HR, BP, and $\dot{V}O_2$ yielded similar correlation coefficients implying that Doppler derived data is nearly as reproducible as these well known comparison variables under the given conditions.

In conclusion, the future of the CW Doppler echocardiography seems promising. Much more research however, needs to be conducted before CW Doppler echocardiography finds a place in the assessment of LVF in cardiac patients during maximal graded exercise testing.

Implications and Recommendations for Further Research

Due to the importance of assessing LVF in health and cardiovascular disease, the investigation of the efficacy of CW Doppler echocardiography as a prognostic tool is of great importance. The methodologies used and conclusions drawn in this study have implications for the clinical and research settings. Empirical methods were used to develop three of the four indicies utilized in this study. Due to the fact that these three indicies were found not to be indicators of reproducibility for Doppler assessment, it is suggested that previously tested and accepted indicies of anthropometry be used in future research. An index such as the ponderal index could be used to evaluate body type. Variables such as respiratory frequency and peak ventilatory velocity could be utilized as indicators of the affects of chest wall motion.

The results of this study indicate a relationship between subcutaneous body fat levels and test-retest reliability of Doppler measurements. The affect that the location of body fat such as subcutaneous fat, intra-organ fat or total body fat has on the test-retest reliability of Doppler measurement, however, has yet to be determined. Also the extent to which varying percentages of these body fat distributions affect reliability has not been investigated. The examination of these aspects of body composition could yield valuable information and should be undertaken. A study could be conducted in which levels of subcutaneous body fat would be measured with skinfold calipers, total body fat would be measured by hydrostatic weighing and intra-organ body fat in pertinent areas such as the lungs, heart and aorta could be measured by computed tomography. All subjects would be measured on all dimensions of body fat and assigned to rank ordered groupings for each dimension much like the methodology and analytical procedures used in the present study.

It is speculated that a major source of variance in this study was extranious upper body motion of subjects during data collection. The effect that this factor has on the reproducibility of Doppler measurement could be investigated by testing subjects on a bicycle ergometer and allowing them to move freely during one trial. During the next trial the subjects could be mechanically restrained. The results generated by the two conditions could then be compared.

As alluded to previously, the affects of rapid ventilatory rate and frequency on reproducibility of Doppler measures were not adequately resolved and should be examined in future research. This could be accomplished by measuring these parameters and incorporating the data into a research design similar to the one used in this study.

Another area of concern which remains unresolved is the role that hypertrophy of the upper torso has on the reproducibility of Doppler measures. Perhaps body builders and runners with similar body fat percentages could be submaximally tested to determine the affect that a high degree of muscle tissue has on the collection of reliable data.

Theoretically, ultrasound waves travel through different human tissues at different velocities as indicated in table 7. Thus, varying proportions of different tissues may affect the reliability of an echocardiographic device. It has been demonstrated that attenuation is a function of frequency and varies in soft tissues (Kraus, 1985). Thus, the amount and type of soft tissue along the path of an ultrasound beam may affect Doppler derived data.

The affects that the aforementioned parameters have on the reproducibility of Doppler measures should also be investigated in other subject populations such as cardiac patients, respiratory patients and females in health and disease. Similar methodologies to those already presented

Table 7. Velocity of Ultrasound Waves Through Various Tissues.

Material	Ultrasonic Velocity* (10^3 m•sec^{-1})
Water	1.48
Blood	1.56
Heart muscle	1.56
Fat	1.48
Skin	1.50
Cartilage	1.67
Bone	3.00
Lung (inflated)	0.70

*All measurements were conducted at a temperature of 37°c

#Source: Kraus (1985).

could be utilized with the addition of proper medical supervision and monitoring for subjects with suspected or documented disease.

In conclusion, it has been speculated that a variety of anthropometric factors affect the reliability of Doppler derived data. This study addressed several of these factors on a superficial level. The next logical step is to investigate each factor in greater detail utilizing various subject populations to gain a greater understanding and insight on how these factors interact and relate to Doppler echocardiography.

Appendix A

DETAILED METHODOLOGY

The following procedures were conducted in order to complete the study.

Selection of Subjects

Forty-two apparently healthy males between the ages of 18-43 years were recruited on a volunteer basis as subjects. The researcher attempted to recruit a heterogeneous sample in relation to each of the Anthropometric Indices. Each subject gave informed consent for a protocol approved by the Human Subjects Committee of Virginia Polytechnic Institute and State University.

Experimental Procedures

Each subject visited the Laboratory for Exercise, Sport and Work Physiology on three occasions. The initial visit served as an orientation session. The objectives and procedures of the study were explained, background information was collected (see Appendix B & F), the informed consent procedure was administered (see Appendix C), pre-test instructions were given (see Appendix F), and a mock testing situation on the bicycle ergometer was conducted. The second session consisted of anthropometric data collection and bicycle exercise test one (TT_1). The third session consisted of bicycle exercise test two (TT_2).

Fifteen anthropometric measurements and VC were taken in triplicate with th subject wearing shorts only. The mean of the three recorded trials represented the criterion score with the exception of VC in which the highest value obtained represented the criterion score. See Appendix D for a description of each measurement and Appendix E for a description of the equipment used to collect the anthropometric data.

Body weight was measured using a medical balance. Height measurements were collected using an anthropometer with a small dome shaped air bubble/fluid level placed on the superior surface to insure accuracy. The subject was instructed to stand erect with heels together and heels, buttocks, shoulder blades, and head against a vertical wall. The head was held in the Frankfurt plane.

Width measurements were collected using a GPM sliding caliper with the subject standing erect. Chest depth was measured using a large GPM spreading caliper. Chest and waist girths were measured with a calibrated metal tape measure with the subject standing erect.

During all topical measurements, the subject was instructed to breathe normally. During all girth and breadth measurements, the midpoint of the deviation between inspiration and expiration served as the recorded score.

Measures of skinfold thickness were taken at three sites for an indication of subcutaneous body fat level. The sites measured were the chest, umbilicus, and thigh. (See Appendix D for specific site description). The sites were measured using a Harpenden Skinfold caliper. The subject was instructed to rest his arms at his sides during all measurements. All measurements were recorded to the nearest mm. Unilateral measurements were taken on the right side of the body. Solid identifiable landmarks of the skeletal system served as anthropometric landmarks, not soft tissue.

After collection of topical anthropometric data, vital capacity was determined utilizing a Collins water sealed spirometer. A brief demonstration of the most effective technique was performed. One raises the arms, stands erect and inhales maximally followed by placing the mouth over a cardboard cylinder attached to the intake hose and exhaling maximally while bringing the arms in toward to torso and bending forward. A noseclip is worn during this procedure to prevent air loss from the nasal passages.

Anthropometric data collection and testing of VC were conducted prior to bicycle exercise testing to avoid the effect of recent exercise on these parameters.

Data for all anthropometric variables were collected two times in triplicate on the initial 20 subjects tested; this served as a pilot reliability study. The three values for each test trial were then averaged into one representative value for each trial. These two values were then averaged to represent the criterion score. The ratio coefficient between TT_1 and TT_2 for all variables exceeded $r = .95$ except those for skinfold measurements which averaged $r = .85$, thus they were retaken for the remaining 20 subjects during TT_2. A correlation coefficient of .95 or greater was selected for acceptability during the pilot reliability study.

The second portion of the data collection and testing sessions comprised a maximal bicycle ergometer exercise tolerance test. Prior to testing the gas analysis system was calibrated and the ambient air temperature, humidity, and barametric pressure were recorded. The subject was prepared for ECG monitoring using electrodes placed for a standard 12-lead recording, and then he was positioned supine on a cot for resting measurements of heart rate (HR), blood pressure (BP), and the Doppler parameters of peak acceleration (pkA), peak velocity (pkV) and stroke velocity integral (SVI).

pkA, pkV, and SVI were measured using a continuous (CW) Doppler system manufactured by Quinton Industries, Seatle, Washington. A hand held probe was placed at the suprasternal notch and angulated to emit an ultrasound beam parallel to the direction of blood flow in the ascending aorta. This is accomplished through auditory, visual and digital hard copy feedback processed by the CW Doppler device. It is assumed that, in the absence of stenotic or valvular heart disease, the greater the Doppler audio output generated by the CW Doppler, the more aligned the ultrasound beam is to the flow of blood (Kisslo, 1986). The greater the Doppler shift frequency the louder the immediate auditory feedback, the greater the immediate visual feedback and the greater the recorded pkV and pkA values on the analog feedback. Thus, the technician positioned the probe on the subject's suprasternal notch until the feedback received indicated the highest auditory signal. Conducting gel was used on the transducer head and the subject's suprasternal notch to aid signal transmission. The researcher wore stereo headphones when receiving auditory feedback to prevent the subject from hearing it, which could have resulted in a biofeedback effect or confusing the CW Doppler generated sound with that of the metronome. They were also worn to make variations in auditory feedback from the CW Doppler instrument more easily discernable to the investigator.

The subject then took his position on the bicycle ergometer, the seat was adjusted and seat height noted, baseline data were then collected. The respiratory gas collection and analysis equipment was engaged and the metronome activated, the subject then began freewheeling until he was able to maintain the proper cadence of 50 rpm, the pedaling resistance was then increased to begin the first stage.

The protocol utilized in this study consisted of seven 3 minute stages with an initial power setting of 50 watts and an increase of 50 watts for each stage thereafter. Expired minute respiratory gas volume, expired O_2 and CO_2 gas concentrations, and HR were measured and collected each minute of exercise. BP was measured between minute one and two of each stage and pkA, pkV, and SVI were measured between minute two and three of each stage (see Figure 1). Subjects were encouraged to complete a given stage before terminating the test. The test was terminated upon request, when the subject was no longer able to maintain the proper cadence, or if any serious signs or symptoms were detected (see Appendix F).

technician one		BP	pkA, pkV, SV1
technician two	HR & VO_2	HR & VO_2	HR & VO_2
	1	2	3

Time (min)

Fig. 1. Timing for measurement by technicians during each stage of the bicycle test.

Upon completion of the bicycle exercise test the subject was either instructed to lay on the cot or remain seated while post-exercise BP, HR, pkA, pkV, and SVI were collected at 2 minute intervals for 8 minutes. Subjects were subjected to both post-exercise conditions, the order of which was determined through randomization (see Appendix F for exercise data collection forms). Aside from the post exercise posture both bicycle exercise test trials were identical.

Prior to each data collection session each subject was asked if he had followed all pre-test instructions and if he wished to perform the test. If the subject answered yes to both questions, testing proceeded; if he did not, he was dismissed.

Research Design

The design utilized in this study was a test-retest comparison. Two graded bicycle exercise tolerance tests were administered on non-consecutive days to a sample population differentiated by four anthropometric indicies.

The dependent measures were examined for stability reliability between the two exercise tests.

Statistical Analysis

The scores from all subjects for each anthropometic index (see Appendix D for description of each index) were rank ordered (see raw data). Within each index the 15 highest scores comprised the high group, the 15 lowest scores comprised the low group and the 12 medical scores were not utilized. An Independent t-test was then performed to determine if the high and low groups for each index were statistically different (see table 1). These rankings were utilized to assign each subject's Doppler measures to the appropriate groups.

The Doppler derived variables of peak acceleration, peak velocity and stroke velocity integral served as the dependent measures. The dependent measures were investigated during 3 levels of exercise intensity; low, moderate and peak. Each subject's true $\dot{V}O_2max$ for each exercise test was utilized to establish the stage at which each exercise intensity level occurred. VO_2max. represented the peak level, ¬66% of $\dot{V}O_2max$ represented the moderate level and ¬33% of VO_2max represented the low level.

A Pearson's Product-Moment correlational analysis was then performed for each of the 3 dependent measures in the high and low anthropometric groups at each of the 3 levels of exercise berween exercise test one and two.

APPENDIX B

Raw Data and Additional Tables

ID	T	PKA			PKV			SVI			SK	CW	WD	VV	HEART RATE		
		L	M	P	L	M	P	L	M	P	RANKING				L	M	P
01	1	50	50	23	0.88	1.06	0.85	07.6	09.8	12.8	26	07	29	24	091	150	166
02	1	36	20	13	0.99	0.86	0.48	09.0	11.6	09.4	17	20	39	04	087	125	187
03	1	49	42	19	0.87	1.05	0.74	08.4	12.6	12.2	21	42	09	29	094	130	181
04	1	35	27	15	0.64	0.79	0.66	05.4	08.8	10.4	14	17	32	05	085	160	187
05	1	55	60	21	1.11	1.26	0.83	09.0	11.8	13.6	29	18	12	12	100	170	181
06	1	36	34	16	0.80	0.99	0.71	05.8	09.6	09.2	19	41	01	02	100	148	200
07	1	40	24	18	0.78	0.75	0.81	06.6	09.8	13.6	34	12	31	32	102	140	200
08	1	50	36	17	0.80	1.07	0.80	05.6	12.8	13.4	01	34	23	25	073	138	185
10	1	73	68	24	1.41	1.45	1.07	09.2	12.6	16.0	25	26	18	17	087	175	207
11	1	55	65	57	1.02	1.26	1.11	07.2	10.4	13.6	28	30	02	28	105	158	194
12	1	42	46	15	0.75	0.92	0.64	04.0	05.4	06.2	18	05	34	10	115	167	188
13	1	30	55	52	0.71	1.08	0.98	06.0	09.8	09.8	09	38	33	42	100	150	185
14	1	71	66	24	1.54	1.31	0.91	13.6	12.6	11.4	15	39	15	06	096	160	188
15	1	41	28	22	1.02	1.04	0.96	06.4	08.4	11.0	04	25	42	34	091	145	185
17	1	59	66	29	1.26	1.33	1.09	09.4	11.2	14.0	38	09	21	31	110	165	188
18	1	48	78	29	1.00	1.28	1.05	09.6	12.0	15.8	12	27	36	37	115	167	190
19	1	42	33	14	0.88	0.94	0.64	07.6	08.4	07.6	32	32	10	08	111	150	177
20	1	57	61	23	0.88	0.97	0.76	06.8	07.8	08.8	20	35	16	16	096	136	160
21	1	39	39	17	0.73	0.88	0.76	04.2	06.4	14.4	23	28	08	22	122	187	194
22	1	50	61	38	1.29	1.43	1.23	08.0	09.2	12.0	10	36	27	26	120	150	200
23	1	37	42	25	0.84	1.19	0.91	06.6	11.4	10.2	30	40	28	15	078	136	206
24	1	50	70	37	1.03	1.40	1.25	08.8	09.4	12.6	02	10	35	27	105	152	191
25	1	39	22	18	0.84	0.95	0.81	09.2	14.8	13.4	24	13	22	23	100	105	166
26	1	38	51	28	0.77	1.08	1.12	05.6	11.2	15.2	37	06	13	38	120	158	200
27	1	54	54	53	0.94	0.95	1.16	04.6	05.6	13.8	35	21	05	36	107	150	185
28	1	55	41	20	0.99	1.08	0.79	06.8	09.0	09.2	39	14	37	14	108	134	167
29	1	41	36	34	0.84	1.05	1.05	10.0	08.8	10.4	08	23	25	33	107	140	187
30	1	54	60	15	1.01	1.12	0.70	05.2	07.2	10.6	33	04	03	01	099	160	179
31	1	52	38	19	0.93	1.10	0.84	06.8	11.0	13.8	05	11	26	11	071	110	184
32	1	37	26	13	0.96	0.94	0.81	10.4	11.0	13.8	27	08	19	07	103	132	180
33	1	54	36	21	1.17	1.19	0.99	09.2	12.8	14.6	31	02	38	03	103	132	186
34	1	64	53	25	1.32	1.34	1.12	09.4	14.6	16.0	07	22	20	39	111	137	193
35	1	71	57	23	1.62	1.54	1.01	11.6	12.4	14.6	22	29	17	09	112	151	189
36	1	37	34	19	0.95	0.94	0.82	07.8	08.4	09.6	03	31	41	19	099	166	186
37	1	75	49	37	1.26	1.05	0.92	06.4	09.8	12.4	41	03	07	35	095	127	177
38	1	78	40	39	1.44	0.95	1.10	06.6	07.2	12.2	13	16	06	41	112	139	194
39	1	37	55	25	0.70	1.05	0.90	06.6	11.0	14.2	42	15	04	20	100	148	189
40	1	72	45	27	1.51	1.36	1.22	12.0	17.0	19.4	11	19	24	30	095	134	187
41	1	45	40	18	1.01	1.26	0.88	06.8	12.0	13.4	36	24	30	21	098	144	201
42	1	40	44	23	0.85	1.13	0.94	06.0	09.2	11.8	06	37	40	40	110	176	189
43	1	39	39	28	0.75	0.86	0.91	04.6	07.4	12.2	40	01	14	13	093	146	175
44	1	29	23	16	0.70	0.83	0.62	06.0	13.2	10.0	16	33	11	18	076	121	179

ID	T	SYSTOLIC B P			OXYGEN CONSUMPTION			% VALID PTS			TOTAL PTS		
		L	M	P	P	M	L	L	M	P	L	M	P
01	1	148	180	220	39.98	28.18	13.35	100	087	057	25	39	37
02	1	142	156	170	39.12	27.44	16.91	065	078	060	37	45	52
03	1	160	188	206	41.01	26.91	14.39	062	069	044	26	29	27
04	1	116	196	200	42.80	32.38	14.68	064	074	068	36	69	56
05	1	154	194	212	32.94	22.39	13.66	053	061	034	40	44	89
06	1	138	174	190	42.25	28.63	12.43	074	056	050	35	48	52
07	1	130	186	204	33.25	24.75	12.10	080	084	022	35	43	36
08	1	112	150	184	48.94	32.55	14.64	086	081	027	29	43	82
10	1	134	180	208	34.62	26.66	10.94	084	088	082	31	40	49
11	1	122	170	210	41.11	25.69	11.31	075	055	070	41	74	61
12	1	140	152	176	29.47	27.20	12.49	080	065	061	30	31	38
13	1	160	170	190	36.43	24.23	15.03	050	082	070	42	35	46
14	1	142	180	196	43.25	26.62	12.03	100	094	045	27	34	75
15	1	132	166	190	40.38	28.86	14.43	051	091	040	41	46	30
17	1	140	160	192	39.62	23.70	14.82	085	068	079	20	44	58
18	1	164	170	188	46.44	27.42	10.07	087	100	071	31	44	42
19	1	132	170	184	48.23	35.16	17.17	090	073	073	31	49	52
20	1	116	160	170	35.94	26.32	11.75	093	091	076	40	65	50
21	1	110	152	200	31.50	22.03	10.28	076	070	051	34	37	43
22	1	152	190	224	41.74	30.93	16.51	047	067	054	38	43	35
23	1	136	168	200	36.04	23.80	10.64	061	066	066	36	41	56
24	1	152	204	220	55.94	37.82	21.09	089	039	020	38	62	79
25	1	154	164	176	44.59	28.47	18.24	096	078	056	26	32	43
26	1	148	170	180	48.32	35.74	11.93	085	055	052	53	53	89
27	1	130	174	202	36.13	27.31	11.23	086	029	054	37	65	63
28	1	140	180	210	41.08	30.73	11.86	065	071	052	34	41	46
29	1	130	160	200	32.57	22.38	15.06	094	061	026	52	38	53
30	1	120	142	170	30.80	20.63	10.18	068	077	054	47	61	84
31	1	122	164	210	39.45	27.86	12.19	078	076	048	23	34	33
32	1	150	194	224	33.10	22.86	13.46	072	054	056	43	37	59
33	1	140	180	200	35.10	24.94	11.57	097	058	051	30	50	90
34	1	140	170	200	36.39	25.89	12.54	100	078	085	29	37	54
35	1	154	196	200	40.60	28.57	14.84	098	088	089	60	64	81
36	1	146	182	210	46.99	30.71	17.43	094	067	080	31	64	30
37	1	130	210	236	28.25	20.14	08.88	054	083	050	41	48	46
38	1	120	138	150	37.95	24.62	15.58	077	040	035	62	50	60
39	1	160	198	192	32.51	22.72	12.19	078	075	047	41	44	76
40	1	146	170	174	56.41	40.42	20.13	096	083	070	25	40	70
41	1	124	146	180	39.92	27.52	12.38	072	090	071	47	48	79
42	1	130	190	196	54.15	38.09	17.41	073	077	040	37	48	40
43	1	160	200	210	38.78	24.67	14.73	067	062	063	45	73	24
44	1	120	162	170	39.51	30.04	10.82	087	069	072	31	58	53

ID	T	pKA			pKV			SVI			HEART RATE		
		L	M	P	L	M	P	L	M	P	L	M	P
01	2	55	56	22	0.96	1.01	0.83	07.0	08.8	13.4	092	136	188
02	2	33	27	20	0.95	0.92	0.73	08.8	11.6	11.8	120	162	188
03	2	50	48	30	0.82	0.95	0.89	06.8	10.4	13.8	098	152	188
04	2	52	53	15	1.13	1.01	0.58	10.6	10.2	08.8	111	171	188
05	2	59	55	23	1.15	1.25	0.99	05.6	13.8	16.2	100	164	195
06	2	33	42	20	0.97	1.03	0.83	09.0	09.2	10.6	102	167	188
07	2	38	38	20	0.69	0.96	0.75	05.0	11.4	13.2	090	150	188
08	2	43	40	19	0.75	1.25	0.85	05.6	14.2	14.2	078	136	177
10	2	80	62	25	1.49	1.32	1.02	09.6	12.6	15.0	115	150	200
11	2	45	53	25	0.81	1.36	1.09	06.4	15.4	17.8	097	137	190.
12	2	43	38	17	0.86	1.04	0.76	04.6	08.6	07.8	107	150	188
13	2	45	45	39	0.95	0.98	0.76	07.4	09.0	07.4	130	150	176
14	2	47	58	26	1.17	1.26	1.00	09.2	10.8	12.4	083	148	177
15	2	47	30	20	1.09	0.98	0.81	07.0	08.2	08.6	100	142	182
17	2	58	31	23	1.18	1.10	0.91	09.6	11.4	14.6	089	122	176
18	2	69	84	29	1.17	1.46	1.10	10.8	14.2	15.8	107	158	195
19	2	42	34	14	1.01	1.05	0.74	08.6	09.2	10.8	097	167	187
20	2	51	56	19	1.00	0.99	0.69	08.2	09.4	09.2	086	140	168
21	2	35	39	16	0.80	0.93	0.75	04.6	08.0	12.2	106	163	182
22	2	38	45	30	0.86	1.27	1.13	05.2	09.8	13.0	099	139	186
23	2	51	35	19	1.17	1.14	0.83	09.6	11.0	13.4	078	138	169
24	2	59	46	26	1.20	1.12	1.13	07.2	08.6	13.0	100	155	170
25	2	34	34	19	0.97	1.09	0.87	10.0	13.0	14.0	099	142	153
26	2	52	50	23	0.98	1.01	0.90	07.2	08.0	11.8	101	188	204
27	2	60	54	30	1.13	1.08	1.17	06.2	06.2	15.4	092	140	178
28	2	46	35	16	0.84	0.97	0.70	06.2	08.8	09.0	075	136	165
29	2	27	29	24	0.67	1.02	0.98	05.0	09.6	10.6	097	159	181
30	2	60	46	23	1.13	1.05	0.84	09.6	12.2	13.0	105	143	156
31	2	55	41	18	1.06	1.06	0.80	09.0	11.4	13.2	082	122	180
32	2	45	29	22	1.12	0.98	0.87	09.8	11.8	11.2	111	139	180
33	2	49	34	22	1.14	1.10	1.07	08.2	11.8	17.8	096	136	182
34	2	68	67	34	1.34	1.56	1.27	09.6	16.6	17.4	107	143	181
35	2	56	50	25	1.43	1.45	1.08	10.8	12.2	14.2	109	155	182
36	2	62	34	22	1.00	0.94	0.84	07.2	08.4	09.4	128	163	194
37	2	54	50	22	0.94	1.11	0.76	05.0	11.0	10.8	095	125	179
38	2	55	40	21	1.25	1.05	0.85	06.6	06.4	08.4	100	140	194
39	2	40	56	21	0.86	1.21	0.90	08.0	13.6	15.4	100	145	183
40	2	70	58	26	1.39	1.42	1.10	11.2	12.4	11.6	113	156	190
41	2	51	58	22	1.26	1.25	0.97	09.4	12.0	11.0	124	146	180
42	2	46	51	20	1.07	1.29	0.85	07.4	10.0	11.2	130	190	196
43	2	40	40	39	0.76	0.87	0.92	06.0	07.4	11.4	098	146	180
44	2	32	46	19	0.70	0.88	0.81	05.6	10.2	14.6	080	125	176

ID	T	SYSTOLIC B P			OXYGEN CONSUMPTION			% VALID PTS			TOTAL PTS		
		L	M	P	L	M	P	L	M	P	L	M	P
01	2	120	130	190	34.10	22.73	03.50	048	069	079	42	29	53
02	2	138	166	200	39.30	25.85	12.66	058	057	058	33	75	85
03	2	140	186	210	38.03	26.42	11.02	074	067	076	34	28	42
04	2	126	160	186	37.05	27.37	13.83	086	080	064	31	32	41
05	2	118	168	180	35.43	25.26	13.16	096	090	050	28	42	44
06	2	130	154	186	29.60	24.78	13.42	075	061	043	36	36	44
07	2	130	160	170	52.85	33.86	15.15	065	068	043	41	60	70
08	2	140	188	208	45.11	29.91	12.49	100	073	079	33	62	62
10	2	140	180	200	38.14	29.47	14.22	080	070	050	30	54	60
11	2	122	170	190	32.09	24.19	12.17	079	073	048	42	33	50
12	2	170	180	188	40.31	23.07	16.13	100	090	047	29	31	47
13	2	142	194	210	42.84	30.11	12.59	052	071	065	42	35	34
14	2	124	170	192	47.83	32.46	15.59	066	071	038	38	34	42
15	2	154	194	200	45.29	35.42	18.96	082	075	068	33	53	63
17	2	162	180	184	40.82	30.27	15.88	089	097	047	28	34	36
18	2	156	174	190	38.98	26.81	13.79	061	083	070	33	24	37
19	2	120	152	160	34.77	24.85	10.98	090	097	087	29	32	30
20	2	132	180	190	35.37	24.28	10.36	088	068	050	41	41	36
21	2	170	220	200	46.39	32.14	17.56	096	082	039	28	34	44
22	2	150	190	228	37.71	26.71	13.39	068	067	045	47	36	33
23	2	174	190	220	53.80	34.18	16.56	085	080	034	41	30	47
24	2	140	150	200	29.52	18.21	12.23	059	094	066	44	32	44
25	2	162	166	194	42.14	29.13	12.70	090	073	048	41	48	64
26	2	140	166	172	38.30	26.23	10.97	069	072	049	32	36	59
27	2	134	176	210	38.46	29.25	11.26	073	056	048	33	39	48
28	2	168	178	220	39.53	23.98	15.98	085	072	018	33	39	33
29	2	116	156	169	33.85	27.04	09.92	055	049	026	61	91	31
30	2	110	162	204	49.48	29.40	15.00	063	078	057	43	37	82
31	2	160	180	218	33.43	22.84	10.77	096	070	053	28	47	51
32	2	134	152	170	34.12	24.98	11.14	091	048	063	22	29	60
33	2	148	180	220	42.72	28.04	13.40	097	081	066	30	37	62
34	2	174	200	230	39.73	26.90	12.78	084	093	083	38	28	36
35	2	140	108	192	38.66	26.58	15.35	094	067	055	32	64	71
36	2	150	194	220	28.51	19.62	09.85	074	076	049	46	59	41
37	2	140	150	164	40.72	22.62	16.30	059	083	047	41	65	45
38	2	164	184	190	32.27	23.16	09.87	036	071	053	47	52	86
39	2	140	170	190	43.31	24.77	13.51	084	067	061	43	42	69
40	2	120	150	180	37.88	25.49	82.48	086	085	054	51	47	41
41	2	160	170	190	52.03	38.43	21.08	083	053	020	41	55	41
42	2	153	188	208	35.22	24.16	11.88	068	070	026	31	53	50
43	2	140	144	190	32.40	19.83	14.30	092	089	043	36	37	54
44	2	150	210	210	43.50	28.90	15.28	078	077	066	27	39	62

Table 8. Characteristics of All Subjects in Study

Age yr		Weight kg		Predicted Body Fat* %		$\dot{V}O_2max$ ml•kg^{-1}•min^{-1}		n
$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	
23.8	5.2	78.6	15.4	11.8	4.3	40.3	6.9	42

Values are means SD.

*Generalized Skinfold equation for males (Jackson & Pollock, 1984).

Table 9. Characteristics of Subjects Utilized in the High and Low Skinfold Groups.

Age yr $\bar{X}$	Age yr SD	Weight kg $\bar{X}$	Weight kg SD	Predicted Body Fat* % $\bar{X}$	Predicted Body Fat* % SD	$\dot{V}O_2max$ $ml \bullet kg^{-1} \bullet min^{-1}$ $\bar{X}$	$\dot{V}O_2max$ $ml \bullet kg^{-1} \bullet min^{-1}$ SD	n
High Group								
24.1	5.9	87.0	20.5	16.1	3.9	37.2	5.3	15
Low Group								
22.4	5.1	71.0	6.6	7.9	2.1	45.8	6.6	15

Values are means SD.

*Generalized Skinfold equation for males (Jackson & Pollock, 1984).

Table 10. Characteristics of Subjects Utilized in the High and Low Chest-Waist Circumference Ratio Groups.

Age yr		Weight kg		Predicted Body Fat* %		$\dot{V}O_2max$ $ml \bullet kg^{-1} \bullet min^{-1}$		n
$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	
High Group								
23.9	5.0	74.8	7.3	10.2	2.5	40.4	6.4	15
Low Group								
26.2	6.3	87.1	20.6	14.9	5.2	39.2	8.3	15

Values are means SD.

*Generalized Skinfold equation for males (Jackson & Pollock, 1984).

Table 11. **Characteristics of Subjects Utilized in the High and Low Upper Torso Width-Depth Ratio Groups.**

Age yr		Weight kg		Predicted Body Fat* %		$\dot{V}O_2max$ $ml \bullet kg^{-1} \bullet min^{-1}$		n
$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	
High Group								
23.7	6.4	73.3	8.7	11.0	4.8	40.5	7.4	15
Low Group								
23.9	4.2	87.1	20.4	13.9	4.3	36.9	4.9	15

Values are means SD.

*Generalized Skinfold equation for males (Jackson & Pollock, 1984).

Table 12. Characteristics of Subjects Utilized in the High and Low Peak Ventilation - Vital Capacity Ratio Groups

Age yr		Weight kg		Predicted Body Fat* %		$\dot{V}O_2max$ ml•kg^{-1}•min^{-1}		n
$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	
High Group								
21.5	2.2	77.0	17.1	11.4	4.6	42.0	7.7	15
Low Group								
24.5	6.7	79.3	13.2	13.0	4.5	37.4	4.7	15

Values are means SD.

*Generalized Skinfold equation for males (Jackson & Pollock, 1984).

Table 13. Means and Standard Deviations for the Total Number of Collected EXERDOP Data Points and the Percentage of Valid Data Points.

	Exercise Intensity					
	Low		Moderate		Peak	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
$Total_1$	35	10	41	16	51	17
$Total_2$	36	9	47	12	54	18
% $valid_1$	75	19	72	16	52	18
% $valid_2$	79	15	72	15	57	17

Appendix C

Informed Consent and Human Subjects Approval Forms

The following forms are utilized in this study in conjunction with another study conducted by Alan D. Moore. Both studies utilized the same sample as subjects.

CERTIFICATE
OF
APPROVAL FOR RESEARCH
INVOLVING HUMAN SUBJECTS

Division of HPER

The Human Subjects Committee of the Division of Health, Physical Education and Recreation has reviewed the research proposal of:

Ronald S. Hoechstetter

entitled: Effect of Anthropometric Factors on the Reproducibility of Doppler Echocardiographic Measurements During Stationary Bicycle Exercise in Healthy Males.

The members have judged the subjects participating in the related experiment (not to be at risk) as a result of their participation.

(If a risk proposal) Procedures have been adopted to control the risks at acceptably low levels. The potential scientific benefits justify the level of risk to be imposed.

Members of Divisional
Human Subjects Committee

____________________ ____________________
Chairman Date

____________________ ____________________
Date

____________________ ____________________
Date

REQUEST FOR APPROVAL OF RESEARCH PROPOSAL IN THE DIVISION OF HPER

Submitted to

Charles Baffi
Chairman, Division Human Subjects Committee and/or
Chairman, Institutional Review Board

by

Ronald S. Hoechstetter
Principal Investigator

and

William G. Herbert
Faculty Sponsor

TITLE: Effect of Anthropometric Factors on the Reproducibility of Doppler Echocardiographic Measurements During Stationary Bicycle Exercise in Healthy Males.

BACKGROUND/SCIENTIFIC JUSTIFICATION: At present the two methods most frequently employed for the assessment of left ventricular function are two-dimensional echocardiography and nuclear ventriculography (Bennett, et al, 1984). Both of these methods are extremely expensive, require extensive technician training, and in the latter method the use of radioisotopes. Recent technological advances have led to the development of a Doppler echocardiographic system designed for use during exercise testing that avoids the problems associated with the above mentioned methods. If found to be reliable this system (EXERDOP) may find use in clinicial and research settings. The EXERDOP system uses ultrasonic energy to measure the blood flow in the ascending aorta. No adverse effects have been documented with the use of ultrasonic devices, and it is considered to be a technique that is even safe enough for routine prenatal examinations (Moore, 1987).

PURPOSE(S): The purpose of the study is to determine the reliability of the EXERDOP system during maximal cycle tests held on separate days (Moore, 1987).

EXPERIMENTAL METHODS & PROCEDURES: The subjects of the experiment will be males less than 35 years of age that are in the category of "apparently healthy" as set forth by the American College of Sports Medicine (ACSM, 1986; see attached), and will be students and faculty/staff members from Virginia Tech. During the initial visit to the laboratory subjects will be screened for contraindications to exercise testing, and will be measured for percentage body fat with skinfold calipers.

During the experimental test the subject will exercise on a cycle ergometer. The workloads will advance 50 Watts every 3 min. Heart rate will be continuously monitored and blood pressure will be recorded each stage. Expired respiratory gasses will be collected through a one-way non-rebreathing valve for calculation of oxygen comsumption. Measurements of aortic blood flow will be conducted during the final minute of each stage with the EXERDOP system.

The subject will be requested to exercise until they are unable and/or unwilling to continue. At this time a monitored cool down period will be administered.

STATEMENT DESCRIBING LEVEL OF RISK TO SUBJECTS: The subjects will be screened according to the ACSM guidelines. The level of risk inherent in exercise testing subjects in the "apparently healthy" category under the age of 35 is minimal, however the following may occur: 1)abnormal changes in heart rate and rhythm, 2) extreme change in blood pressure, 3) fainting, 4) very rare instances of heart attack, 5) leg fatigue, 6) skin irritation caused by electrode preparation for ECG, and/or 7) minor soreness above the sternum where the EXERDOP transducer is positioned.

PROCEDURES TO MINIMIZE SUBJECT RISK (IF APPLICABLE): The subjects will be screened prior to any participation in the study. The primary investigator and two of the technicians are certified by ACSM for exercise testing and supervision. All of the laboratory technicians are certified in CPR. Heart rate and rhythm will be continuously monitored electrocardiographically to permit rapid detection of abnormalities if they should arise. A telephone will be available for the investigators to phone the rescue squad if necessary.

RISK/BENEFIT RATIO (IF RISK PROJECT): The risk to the subjects is minimal. The subjects will learn their oxygen comsumption which is the criterion measurement of aerobic fitness. The benefit to the research and medical community will be great if the EXERDOP proves to be a reliable indicator of left ventricular function.

LABORATORY FOR EXERCISE, SPORTS, AND WORK PHYSIOLOGY

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

INFORMED CONSENT

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

Title of Study: Effect of Anthropometric Factors on the Reproducibility of Doppler Echocardiographic Measurements During Stationary Bicycle Exercise in Healthy Males.

The purposes of this experiment include: To examine the reliability of a new Continuous-Wave echocardiographic device during maximal cycle testing (Moore, 1987).

I voluntarily agree to participate in this testing program. It is my understanding that my participation will include: Two tests on a cycle ergometer to maximal exercise levels. Each test will last from 12-18 min. During these tests the investigators will constantly monitor heart rate and rhythm, will measure blood pressure once every 3 min., will continuously collect my expired respiratory gasses, and will determine aortic blood flow with an echocardiographic device every 3 min. The blood flow determintation will be made by a technician placing a hand-held probe above my sternum (the area where my neck and chest meet).

I understand that participation in this experiment may produce certain discomforts and risks. These discomforts and risks include: Abnormal changes in heart rate and/or rhythm, abnormal changes in blood pressure, fainting, very rare instances of heart attack. leg fatigue, skin irritation due to skin preparation for ECG monitoring, and minor soreness above the sternum from the pressure of the technician holding the probe in place for the blood flow measurements.

These risks will be minimized by screening for contraindications for me to exercise. The primary investigator and two of the laboratory technicians are certified by the American College of Sports Medicine for exercise testing and supervision, and all of the technicians are certified in CPR.

Certain personal benefits may be expected from participation in this experiment. These include: The subjects' maximal oxygen uptake, which is the criterion measure of aerobic fitness.

Appropriate alternative procedures that might be advantageous to you include: The subject will be excluded from the study if any changes occur during the exercise tests that make it hazardous to continue.

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

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

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

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

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

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

_____ I request a copy of the results of this study.

Date ______________________ Time _____________a.m./p.m.

Participant Signature ______________________________

Witness ___________________________________
HPL Personnel

Project Director ________________ Telephone _____________

HPER Human Subjects Chairman Dr. Charles Baffi
Telephone 961-6561.

Dr. Charles Waring, Chairman, International Review Board for Research Involving Human Subjects. Phone 961-5283.

Appendix D

Definition of Indices, Measurement Sites and Additional

Pertinent Terms

Anthropometric Indices

1. Sum of skinfolds (SK): Sum of chest, abdominal and thigh skinfolds ($\pm$1mm). This serves as an indication of subcutaneous fat levels.
2. Chest girth-waist girth ratio (CW): Ratio of chest circumference to waist circumference. This serves as an indication of meso-endomorphy.
3. Biacromial width-chest depth ratio (WD): Ratio of breadth to depth of the upper torso. This serves as an index of "deep chestedness" vs. "shallow chestedness".
4. Ventilatory-forced vital capacity ratio (VV): Ratio of maximal minute ventilation to forced vital capacity.

Skinfold Measurement Sites

Abdominal: A vertical fold taken at a lateral distance of approximately 2 cm from the umbilicus.

Chest: A diagonal fold taken one half of the distance between the anterior axillary line and the nipple.

Thigh: A vertical fold on the anterior aspect of the thigh, midway between the hip and knee joints.

Anthropometric Measurement Sites

Biacromial breadth: Distance in cm (±1mm) between the most lateral points of the acromion processes.

Biiliac breadth: The distance in cm (±1mm) between the most lateral points on the superior border of the iliac crests.

Cervical height: Distance in cm (±1mm) between the support surface and to the most posterior point of the second cervical vertebrae.

Chest breadth: Breadth in cm (±1mm) of the torso at nipple (thelion) level.

Chest depth: Dorsal to ventral depth of the torso measured horizontally in cm (±1mm) at the level of the fourth intercostal space.

Chest girth: Circumference of the torso measured horizontally in cm (±1mm) at the nipple (thelion) level.

Iliac height: Distance in cm (±1mm) between the support surface and the inferior margin of the anterior superior iliac spine.

Suprasternal height: Distance in cm (±1mm) between the support surface and the superior border of the midline of the manubrium.

Total height: Distance in cm (±1mm) between the support surface the top of the head.

Waist girth: circumference of the torso measured horizontally in cm (±1mm) at the narrowest point from an anterior vantage point.

Additional Relevant Terms

Aliasing - inappropriate (ambiguous) representation of velocities, which exceed the measuring capacity of a pulsed doppler system (Labovitz & Williams, 1985).

Anthropometer - a graduated rod with a sliding branch perpendicular to the rod used to measure body height(s).

Anthropometry - the study of describing the physical characteristics of the human body.

Attenuation - the rate at which the amplitude of an ultrasonic wave decreases as it propagates through tissue (Kraus, 1985).

Body Temperature and Pressure Saturated (BTPS) - a subscript that indicates that a gas was measured at 310 K, 760 mmHg, 100% humidity.

Cardiac Output ($\dot{Q}$) - the quantity of blood flow expressed in liters ejected by the left ventricle in one minute.

Cardiovascular Status - a general term pertaining to the capability of the cardiovascular system to function during exercise.

Doppler Effect - a change in frequency and wavelength, which occurs when either the source or receiver are moving relative to one another. Doppler echocardiography uses the change in frequency of reflected sound to measure the velocity of blood within the heart and great vessels (Labovitz & Williams, 1985).

Doppler Shift - the difference in frequency between the interogating frequency (Fo) and the received frequency. The frequency shift is proportional to the speed of the reflectors (Labovitz & Williams, 1985).

Ectomorphic - pertaining to a light or slender body build.

Endomorphic - pertaining to a pyknic (fat) body build.

Flow Velocity Integral (FVI) - a synonym of systolic velocity integral (Moore, 1987).

Fraction of Expired Carbon Dioxide ($FECO_2$) - the percentage of carbon dioxide present in a subject's expired air.

Fraction of Expired Oxygen (FEO_2) - the percentage of oxygen present in a subject's expired air.

Frankfurt Plane - the standard horizontal plane of orientation of the head. The plane is established by a line passing through the right tragion (approximate ear hole) and the lowest point on the right orbit (eye socket), with both eyes on the same level (Kroemer, 1986).

Laminar Flow - characteristic blood flow in smooth structures defined by parallel direction of flow of most red blood cells, producing a narrow spectral band width (Labovitz & Williams, 1985).

Left Ventricular Function (LVF) - pertains to the ability of the left ventricle to adequately supply blood to the systemic circulation at rest and more importantly during exercise.

Maximal Volume of Oxygen Consumption ($\dot{V}O_2max$) - the maximal quantity of oxygen a subject can utilize per unit time, usually one minute.

Mesomorphic - pertaining to a muscular, large boned body build.

Minute Ventiltion ($\dot{V}_E$) - the total volume of gas expired per minute by an exercising subject (Ruppel, 1986).

M-mode Echocardiography - a form of imaging echocardiography that displays in a single dimension known as an "ice pick" view (Harrigan & Lee, 1985).

Morphology - a branch of biology that deals with the form and structure of animals and plants (Webster's Third International Dictionary, 1961).

Nyquist Limit - inability of pulsed Doppler to measure (resolve) frequencies of more than one half of the pulse repetition frequency (Labovitz & Williams, 1985).

Ponderal Index - a morphological index which yields a value calculated by dividing an individual's height by the cubed root of his or her weight.

Pneumotachometer - an air flow sensing device (Ruppel, 1986).

Pulsed Wave Doppler (PW) - a Doppler echocardiographic method used to measure the velocity of blood. A PW Doppler uses one transducer to transmit sound energy in pulses and receive the reflected signal (Labovitz & Williams, 1985).

Respiratory Rate (f) - the number of breaths taken per unit time, usually one minute.

Sample Volume - Area from which sound is analyzed in pulsed doppler, defined by length (range gate) and the width and depth of the interrogating beam (Labovitz & Williams, 1985).

Somatotype - a classification of human body-build in terms of the relative development of ectomorphic, endomorphic and mesomorphic components (Webster's Third International Dictionary, 1961).

Standard Temperature and Pressure Dry (STPD) - a subscript that indicates that a gas has been mathematically standardized to 273°K, 760 mmHg and 0% humidity.

Stroke Distance (SD) - syncnym for systolic velocity integral.

Stroke Volume (SV) - the quantity of blood expressed in ml ejected from the left ventricle per contraction.

Three-dimensional Echocardiography - a form of imaging echocardiography which utilizes computers to compile multiple cross-sectional views, also known as reconstruction echocardiography (Harrigan & Lee, 1985).

Turbulent Flow - flow characterized by multiple directions and velocities of red blood cells, usually occurring in the presence of an obstruction to flow (Labovitz & Williams, 1985).

Two-dimensional Echocardiography - a form of imaging echocardiography that displays in two dimensions, also known as cross-sectional echocardiography (Harrigan & Lee, 1985).

Vital Capacity (VC) - maximal volume of air one can expel following a maximal inspiration (measured to the nearest deciliter)

Volume of Carbon Dioxide ($\dot{V}CO_2$) - the quantity of carbon dioxide generated in one minute.

Volume of Oxygen Consumption ($\dot{V}O_2$) - the quantity of oxygen utilized by a subject per unit time, usually one minute.

Water Sealed Spirometer - an instrument used to noninvasively determine lung volumes.

Appendix E

Equipment Utilized in Study

Air pump: #2, Neptune Dyna-Pump, Universal Electric Co.

Alcohol swabs: B3062, American Scientific Products

Anesthesia bag: 2 liter, Intertech Ohio

Anthropometer: GPM, Swiss made

Bicycle ergometer: Monark No. 868

B.P. apparatus: Trimline, PyMaH Inc.

Cuff: Tycos

Breathing valve: Daniel's valve

Calibration gases: Airco Industrial gases

CO_2 analyzer: CD-3A, Applied Electrochemistry Inc.

Sensor: P-61B, Applied Electrochemistry Inc.

Pump: R-1, Flow control, Applied Electrochemistry Inc.

Collin's water sealed respirometer: Timed Vitalometer, Warren E. Collins Inc.

Doppler (Continuous wave): "ExerDop", Quinton Instrument Co.

Drierite: desecating agent

ECG recorder: 1514C ECG-Phono System, Hewlett-Packard

Electrodes: Quick-Trace ECG Monitoring electrodes, Quinton Instrument Inc.

Electronic Metronome: LM-4 Franz Manufacturing Co.

Large spreading calipers: 52808, GMP Swiss made

Medical balance: Detecto-Medic

O_2 analyzer: 5-3A, Applied Electrochemistry Inc.

Sensor: N-22M, Applied Electrochemistry Inc.

Pump: R-1, Flow control, Applied Electrochemistry Inc.

Pneumotach: 47303A, digital pneumotach verbex series, Hewlett-Packard

Skinfold calipers: Harpenden

Steel measuring tape: True value master mechanic

APPENDIX F

Data Collection Forms

Subject Instructions

Exercise Test Termination Criteria

Subject Background Information

Anthropometric Data Form

Subject's name ____________________ Age ________

Date & Test #	/ /			# 1	/ /			# 2	
Weight									
Trial & C.S.	1	2	3	C.S.1	1	2	3	C.S.2	T.C.S.
Height Total									
Cervical									
Suprasternal									
Iliac									
Transverse Biiliac									
Chest breadth									
Biacromial									
Chest depth									
Chest girth									
Waist girth									
Skinfolds Chest									
Umbilicus									
Thigh									
Total									
Vital Capacity									

SUBJECT INSTRUCTIONS

Thanks for helping us conduct our research. We are examining a new device that should help in the evaluation of cardiac status. If the device proves to be a reliable instrument it may one day find a place in the assessment of cardiac disease.

There are a few things that you need to make sure to do or avoid doing before the testing sessions. This is to assure that your cardiac responses to exercise will be as similar as possible during the two tests. They are listed below.

1) If you currently lift weights as part of your personal fitness program, avoid any leg work for at least 48 hours prior to testing (you will be performing a cycle test and need to have your legs rested).

2) If you normally run, swim, cycle, or perform other aerobic activities please do not exercise on the days you are to be tested. (Exception: If you are in a swimming class such as ALS or WSI, participate normally in learning the skills your instructor assigns for that day, but do not swim laps or exert yourself more than moderately.)

3) Do not eat or drink anything other than water or diet soft drinks for 3 hours prior to your scheduled testing time, if you do eat a meal more than 3 hours before your test have only a light meal.

4) Try to get a good nights rest (about 7 hours or more of sleep) the night prior to your test. For most of us it will be a welcome change!

Once again, thanks for everything. The findings of this reserach project should contribute in a significant way to the field of diagnostic exercise testing, and it would not be possible without your participation.

Your assigned time for testing is ______________________. The exercise lab is in Gym 230 (second floor, back of the building). If you can't make it for any reason please call either:

Alan Moore	951-1505
Ron Hoechstetter	961-3277
Lab	961-5006

Exercise Test Termination Criteria

1. Subject request

2. Equipment failure

3. Abnormal BP, HR, or respiratory response

4. Light headedness, confusion, ataxia, pallor, cyanosis or nausea

5. Inabiltiy of subjects to maintain cadance.

Reference: American College of Sports Medicine (1986).

Subject Background Information Sheet

Name

Age

Phone #

Address (local)

Address (permanent)

Physical Activity Habits

Activity	Duration per session	Sessions per week
1.		
2.		
3.		
4.		
5.		

Do you take any medication? If so what?

Circle all illnesses you have had:

mononucleosis	pulmonary disease	emotional disorders
diabetes	asthma	drug allergies
epilepsy	emphysema	other ______________
high blood pressure	bronchitis	

Do you have any medical or orthopedic problems? If so, what?

Have you had any recent illness or hospitalization?

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