# THE ACUTE METABOLIC AND HEMODYNAMIC EFFECTS OF BODY INVERSION DURING REST AND EXERCISE

by

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(ABSTRACT)

Suspension of the body in the head-down posture (90° below the horizontal) for traction and added resistance to exercise has generated considerable interest in recent years. However, recent investigators of inversion have cautioned individuals not to participate in such activities until further research could be performed on the effects of exercise in the head-down position.

The purpose of this investigation was to examine the acute metabolic and hemodynamic responses of men at rest and during exercise in the inverted posture (90° head-down tilt) versus the supine and standing postures. The parameters investigated were oxygen consumption($\dot{V}O_2$), heart rate(HR), systolic blood pressure (SBP), and diastolic blood pressure(DBP). Eleven male recreational athletes underwent 6 sessions of postural change. The baseline posture was sitting and the critical positions were supine, standing, and inverted. The subjects were asked to remain in each of these postures for three minutes. In the first 2 sessions, oxygen

consumption($\dot{V}O_2$), was measured at rest and during 45° hip-flexion respectively, The $\dot{V}O_2$ in the inverted posture at rest was found to be 1.7% greater than the $\dot{V}O_2$ in the standing and the supine postures. $\dot{V}O_2$ in the inverted posture during exercise was 7% and 36.5% greater than in the supine and standing postures, respectively.

A statistical significance in HR at rest in the standing posture versus the inverted and supine postures was observed. During 45° hip-flexion activity, the HR in the standing posture was found to be significantly faster than the supine posture. The HR in the inverted posture was significantly faster than the supine posture as well.

At rest, there was no significant increase in SBP as related to posture. During exercise, the SBP was significantly greater at rest in each of the postures.

Both postural and exercise factors significantly affected the DBP. The post-hoc analyses showed supine resting DBP was significantly lower than in the other two resting postures. During exercise, the standing BP was significantly greater than the supine and inverted DBP.

These data demonstrate: A) $\dot{V}O_2$ in the supine and inverted postures is significantly greater than in the standing postures. B) a statistically significant increase in HR occurs in the standing posture as compared to the supine and inverted postures; however, it does not appear to be clinically significant, C) with the arms maintained in the anatomical position for all postural changes, the SBP was not significantly affected by the change of posture, but was significantly increased with exercise. D) and DBP in the standing posture was statistically greater than in the other two postures and DBP in the inverted posture was significantly elevated above that found in the supine posture.

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## Chapter I

## Introduction

The American Medical Association (3) has estimated that 80% of all people will suffer low back pain during their lifetime. They report that the most widely accepted treatment for chronic low back pain syndrome (LBPS) with neurological involvement is the laminectomy or surgical removal of the nucleus pulposus (commonly known as the disc). During the late 1960's, Dr. Robert M. Martin, an orthopedic surgeon, reasoned that most atraumatic LBPS originated from man's failure to counteract the compressive forces of gravity and poor posture resulting in loss of the normal curvature of the spine. He developed the Decompression Mobilization Conditioning Program, a program based on the concept of corrective exercises designed to simultaneously stress and mobilize the joints of the body as they stretch soft-tissue structures (30,31). Dr. Martin invented inversion boots™ and later the Gravity Oscillator™ to counteract the compressive forces of gravity by allowing the patient to assume a position of a $-90^{0}$ head-down tilt. Although originally designed by Martin to be used only while performing certain inversion exercises, many people use the equipment to hang "upside down" in a static manner.

Suspension of the body in the head-down position ($90^{0}$ below the horizontal) for traction and added resistance to exercise has generated considerable interest in recent years. The physiological effects of static head- down tilt to $60^{0}$ below the horizontal in non-exercising subjects has been well documented (6, 10, 14). Definitive research has been done by NASA investigators and others (25) concerned with human motor performance and physical fitness under various gravitational stresses. Probably the major deterrent in the past to investigations of more stressful tilts than -60$^{0}$, i.e., between 60$^{0}$ and 90$^{0}$ head-down positions, has been the lack of a suitable means to support the body weight without undue mechanical stress on the legs or shoulders. The development of a suitable inversion apparatus, such as inversion boots which allow one to hang from the ankles, provides opportunities to extend present knowledge of the human hemodynamic adaptations to conditions involving combinations of postural and exercise stressors. Also, the Martin inversion apparatus provides a method for determination of the efficacy and contraindications for using such techniques in health maintenance and clinical rehabilitation circumstances.

Recent investigations (22,27) have demonstrated significant elevations in arterial blood pressure during passive inversion. LeMarr, Golding, and Crehan (27) reported statistically significant elevations of systolic and diastolic blood pressure during passive inversion with the arms hanging in a dependent position above the head. They reasoned, because exercise typically increases the blood pressure, exercise in the inverted posture might increase the blood pressure even more. LeMarr and his associates (27) recommended, therefore, that exercise in the inverted posture be avoided until further research on exercise in the inverted posture is completed. Sheppard (39) followed on LeMarr's cautions with a suggestion that the increase of pressure in the head could possibly lead to a rupture of a "berry" aneurism or small blood vessel in the head that has become weak due to some pathological condition. Ameliorating Sheppard's concerns, somewhat, are other published findings (16) demonstrating that normotensive man can withstand gravitational forces up to and probably exceeding five times earth's gravitational load. Also, Renfrew (37), in an editorial to the Physician and Sports Medicine, questioned LeMarr's measurement technique for blood pressure, contending that elevations observed in blood pressure taken with the arms hanging beside the head instead of using the procedure recommended by the American Heart Association was the reason for the elevated response. This procedure recommends that the cuff of the sphygmomanometer be placed over the appropriate artery (in this case the brachial) and the arm maintained at the level of the heart (2).

Because of observed elevations in systolic and diastolic blood pressure in 20 young adults during inversion, Klatz, Goldman, Pinchuk, Nelson, and Tarr (22) speculated that inversion may be contraindicated in certain patient populations. However, in a subsequently published article in the Western Journal of Medicine, Goldman, Tarr, Pinchuk, Kappler, Slick, and Nelson (13) revised their precautions and stated that the possibility of cerebrovascular accident has been grossly exaggerated by the media. They support their reasoning by reporting that up to the time the article was written, not a single case of reported stroke or cerebrovascular accident associated with all forms of inversion therapy over 15 years had been reported. The investigators cited the previous mentioned article on the physiology of negative acceleration (16) illustrating that protection against brain hemorrage may be afforded by the concomitant increase in cerebrospinal fluid. In addition, the investigators stated that blood pressure in the inverted posture by no means increased to the level reported by Carswell (8). Carswell reported the blood pressure response to single bouts of exercise in extensive weight training showed measurements of 450/310 mmHg.

## Statement of the Problem

This study was undertaken to determine both the aerobic energy requirements and hemodynamic responses for eleven normotensive young men during rest and exercise in the supine, standing, and inverted postures. The research design employed also served to clarify the extent to which blood pressure and heart rate responses to exercise during various postures might be explained by the exercise factor, the inversion, or the interaction of the two stressors.

### Null Hypotheses

Specifically, the following null hypotheses were formulated:

$Ho_1$: There was no difference in the oxygen consumption of men at rest in the inverted posture (hanging) versus the supine and standing postures.

$Ho_2$: There was no difference in the oxygen consumption of men performing $45^{o}$ dynamic hip-flexion exercise at fixed rates in the inverted posture (hanging) versus the supine and standing postures.

$Ho_3$: There was no difference in heart rate and blood pressure responses of men at rest in the inverted posture as compared to the supine and standing postures.

$Ho_4$: When the exercise rates are controlled such that oxygen consumption is held constant among postural conditions, there is no difference in heart rate and blood pressure responses of men performing $45^{o}$ hip-flexion in the inverted posture (hanging) versus the supine and standing postures.

## Delimitations

The following delimitations were imposed by the investigator in order to conduct the study using available facilities and equipment:

1. sample size was restricted to eleven young adult males classified as recreational athletes; i.e., not members of organized sport activities and routinely engaged in physical activity levels of similar frequency, intensity, and duration.
2. responses to only three posture changes were evaluated (supine, standing, and $90^{0}$ head-down tilt). Inverted exercise was established as the standard to elicit a $\dot{V}O_2$ by which to match the supine and standing exercise. Therefore, it was considered to be the criterion measure.
3. responses to only one exercise modality, i.e., hip-flexion to $45^{0}$ in each posture were evaluated.

## Limitations

The following limitations were accepted as inherent in the following study.

1. the experimental results were considered applicable to these eleven persons.
2. responses observed in the supine, standing and inverted postures do not necessarily reflect the responses that would be observed in other angles of tilt.

## Definitions and Symbols

### Equipment

Oscillator: device used to invert the body gradually by altering the center of gravity (Figure 1).

Inversion Boots: padded clamps placed around the ankle which hook a bar on the oscillator to suspend the subject in the inverted posture.

Oscillating Sphygmomanometer: instrument used to measure blood pressure through measurement of the amplitude of the pressure pulsations (oscillations) introduced into the cuff by the movement of the arterial wall.

### Physiological Measures

Heart Rate (HR): The frequency of contractions of the heart (usually expressed in terms of beats per minute).

Blood Pressure (BP): The pressure of the blood in the arteries.

1. Systolic (SBP): Blood pressure when the heart muscle is contracted.
2. Diastolic (DBP): Blood pressure when the heart muscle is relaxed between beats (diastole).
3. Mean Arterial Pressure (MAP): The average pressure during a cardiac cycle. MAP is the constant driving force of blood through the arteries. The arterial waveform is not symmetrical through the point of interest and therefore is not an arithmetic mean. Rather, it is a geometric mean and takes into account magnitude and time.

4. Oxygen Consumption ($\dot{V}O_2$): An indirect measurement of the amount of heat given off by the body (usually expressed as $ml \cdot kg^{-1} \cdot min^{-1}$).

Related Terms

Oscillation: While on the bed-style invertor (oscillator), the act of moving from the upright to the inverted posture by altering the center of gravity.

Baroreceptor: A sensory nerve ending that is stimulated by changes in pressure, as those in the walls of the blood vessels.

Carotid Sinus: The dilated portion of the internal carotid artery containing in its wall baroreceptors.

Cardiac Output (Q): The amount of blood pumped out of the heart in one minute.

Stroke Volume (SV): The amount of blood pumped out of the heart during one systole.

## Basic Assumptions

The following assumptions were evident in this study:

1. The hip-flexion movement simulates that movement typically performed by individuals using inversion equipment as a mode of exercise.
2. Subjects exercising in the inverted posture performed the same amount of work by increasing the number of repetitions performed in the standing and supine positions respectively.
3. The rope loops placed around the wrists did not impede blood flow in any manner so as to alter the blood pressure measurement.

# Chapter II

# Literature Review

## Introduction

The aim of this section is to present a review of previous studies on investigations of the hemodynamic and metabolic effects of orthostatic stress. A comprehensive examination of all the physiological factors influenced by orthostatic stress is beyond the scope of this review. Therefore, only articles that report the acute hemodynamic and metabolic effects of various degrees of tilt at rest and during exercise are cited. Specifically, the parameters of systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), heart rate (HR), and oxygen consumption ($\dot{V}O_2$) were examined. The literature relating to the metabolic and hemodynamic responses to body tilt has developed over the past 84 years. This information has been gathered from investigations on traumatic and pathogenic shock, orthostatic stress from aviation technology, and most recently, the use of inversion apparatus for therapeutic and recreational activities.

## Blood Pressure Effects of Postural Change at Rest and During Exercise

### Systolic Blood Pressure

One of the earliest published investigations of orthostatic stress was written by Hill (1898). The subjects were tilted in the supine position to a $-45^{0}$ tilt on a tilt table similar to the one illustrated in Figure 2. Blood pressure (BP) was measured using a sphygomanometer over the brachial artery. The arm was maintained in the frontal plane perpendicular to the long axis of the body throughout the testing. SBP remained approximately the same on tilting from an erect to the $-45^0$ head-down position. These readings were not taken during or immediately following postural change, but after the subject was in an altered position for an appreciable period of time.

Henderson and Haggard (1918) performed one of the first studies specifically focused on investigation of the circulatory effects of the head-down posture. The BP and HR were recorded in the erect, horizontal, and $-45^0$ position of 10 healthy young men. Blood pressure was recorded with the arm alongside the torso; time of measurement was not indicated. There was a large variance in SBP between individuals in each posture; however, no significant difference in BP was noted between the three postures. The investigators remarked that an increase in filling pressure apparently did not affect arterial pressure. Subject discomfort due to the pressure on the shoulders from the tilt table was documented which may have provided a source of measurement error.Ellis (1921) investigated the circulatory responses experienced by aviators. BP and HR were measured immediately and five min after tilting from the standing and supine posture to the $-45^0$ head-down position. Arm position was not noted, but appears to have been alongside the body since he used brachial artery catheterization for BP measurement. Maximum hemodynamic response occurred during the first three min of each new posture, according to preliminary studies. Ellis reported no BP changes varied significantly. Systolic BP decreased in many cases when the subjects were tilted from supine to $-45^0$ or from standing to the $-45^0$ head-down tilt. In half of the subjects, SBP increased when the position changed. In the other half of the subjects, SBP increased, decreased or remained the same. Ellis concluded that BP response was subject to individual variation.

The BP response to standing from the recumbent position was investigated by Wald, Guernsey, and Scott (1937). This was the first investigation of this type that used an automated sphygmomanometer. Upon standing the SBP decreased, but then returned to resting levels after one min and stabilized. These authors concluded that the SBP adjustments to tilting is rapid and that circulatory equilibration should be completed within one min. Although these investigators reported no source of measurement error, one source may be vascular capillary compression caused by taking more than one reading per min.

To differentiate pathological tachycardia from tachycardia resulting from excitement, Green, Iglaner, and McGuire (1948) studied arterial blood pressure responses to $-45^{0}$ head-down tilt (excursion $+20^{0}$ to $-45^{0}$). The $+20^{0}$ tilt, i.e., with head $20^{0}$ above supine, appears to have been chosen because the investigators judged that it presented the most efficient position for the subject to mount the tilt table. Two hundred subjects received brachial or radial artery catheterizations prior to tilting. The arm was supported on an arm board and abducted to a position $90^{0}$ from the trunk. Blood pressure was taken during and immediately after tilting (8 to 18 sec.). A mean elevation of 19 mmHg in SBP was observed during the tilt to $-45^{0}$. The amount of rise in SBP appeared somewhat linear in relationship to the degree of excursion of tilt. The authors reported that when the tilt table was stopped at $-45^{0}$, the blood pressure gradually decreased for 8-18 sec until it was just slightly higher than readings obtained in the erect posture.

Wilkins, Bradley, and Friedland (1950) investigated the acute circulatory effects of the head-down position (-75)° in 42 male and female subjects convalesing from minor illnesses in a hospital. The subjects were placed in a -75$^{0}$ head-down tilt for 2 to 30 min, the duration being dependent on their individual tolerances of the position. Arterial blood pressure was measured using a Hamilton manometer connected to a catheter placed in the brachial or femoral artery. A possible source of measurement error in this investigation was that on tilting quickly head-downwards, there was an immediate sensation of tumbling heels-over-head. Many of the subjects tensed their muscles and grabbed for the sides of the tilt table. It has been well documented that muscle contraction in the arms tend to increase blood pressure (Carswell, 1983). Nevertheless, these investigators reported an immediate increase in brachial arterial SBP, followed by a brief, but stable plateau for two or three pulse beats when tilted to -75$^{0}$ which was followed by a decrease in BP which stabilized after 5-15 sec. The femoral artery SBP always decreased upon tilting to the -75$^{0}$ position. Femoral artery SBP increased upon resumption of the +75$^{0}$ posture while there was little or no change in the brachial arterial SBP.

Sancetta's (1957) work on the acute hemodynamic effects of -35$^{0}$ head- down body tilt was intended to extend the previously mentioned investigation by Green and associates (1948) on hydrostatic responses to head-down tilt. He examined central venous pressure, brachial artery pressure, and cardiac output. Brachial artery catheterization was performed via the antecubital fossa. Ten subjects were tilted from supine to -35$^{0}$ and maintained there for 15 min at which time SBP was significantly elevated. No mention was made of other SBP measurements taken prior to the 15 min interval; therefore, it was not known how much fluctuation occurred over the 15 min. It should be noted that Sancetta did not mention environmental controls during this investigation. It may be likely that the patients were allowed to talk during the testing period. Lynch, Long, Thomas, Malinow, and Katcher (1981) reported that talking may significantly elevate SBP. Thus, failure to keep subjects quietly isolated could prove to be a source of measurement error in this investigation.

Central venous pressure (CVP) and arterial BP changes associated with $-5^0$ tilt were observed by Nixon, Murray, Bryant, Johnson, Mitchell, Holland, Sanchez, Vergne-Marine and Glomgvist (1979). To simulate weightlessness, these investigators placed subjects in the $-5^0$ position for 24 hours. The SBP was measured via brachial artery catheterization and found to decrease from $103 \pm 6$ in the supine posture to $100 \pm 6$ in the $-5^0$ tilt. The response was not clinically significant.

Systolic BP was measured during a plethysmographic study on forearm and finger blood flow responses to passive tilt by Mengesha and Bell (1979). They observed SBP in various head-up and head-down tilts. Five baseline BP measurements were taken in the recumbent position over a 10-15 min period prior to postural change. The subject was then tilted passively to the required position and the measurement of BP started 20-60 sec after the position was assumed. The subject rested in the supine posture for 5-10 min after each tilt. SBP was measured for 10-20 min in the various tilts. The postures examined are $+30^0$, $-30^0$, $+60^0$, $-60^0$, and $+90^0$, respectively. In the head-up tilts, SBP decreased significantly in a somewhat linear fashion (ranging from 113-116 mmHg at

+30$^{0}$; 102-112 mmHg at +60$^{0}$; and 98-112 mmHg at +90$^{0}$). An increase in SBP was observed in head-down tilts in most subjects, but overall the means were not significantly different from baseline supine values. These changes in BP were attributed to the shifting of the blood to the thorax and head in the head-down position and pooling of blood in the legs in the head-up position.

Katkov, Chestutkin, Lapteva, Yakovleva, Mekhailon, Zybin, and Utkin (1980) examined central and cerebral hemodynamics and metabolism in healthy men in response to -20$^{0}$ head-down tilt. Up to nine catheters besides the brachial artery catheter for brachial arterial pressure were utilized. It is obvious that the use of so many catheters may have itself induced experimental bias influencing BP response in this investigation. Nevertheless, the authors reported that SBP did not significantly change during the tilt.

Recent use of gravity inversion devices prompted Klatz, Goldman, Pinchuk, Nelson, and Tarr (1983) to investigate the effects of inversion on systemic BP, pulse rate, central retinal arterial pressure, and intraocular pressure. The investigators subjected 20 healthy participants to a 3-minute inactive period of -90$^{0}$ head-down tilt (complete inversion). Blood pressure was measured by sphygmomanometer with the arm in the coronal plane alongside the body. Both arms were allowed to hang passively beside the head when no measurement was being taken. These investigators reported an increase in SBP measured within 3 min of tilting (from 119$\pm$2.63 to 157$\pm$4.22 mmHg) which remained relatively constant over 3 min. SBP returned to near pre-tilt values immediately upon resumption of the seated posture. They warned that the increased flow of the blood headward and the resultant increase in SBP and DBP may increase cerebral arterial pressure to dangerous levels. A recommendation of caution was issued by the authors aimed at fitness practicioners who prescribe inversion boots. Of greatest concern to the authors was that segment of the population suffering hypertension, cardiovascular disease, and stroke.

In a follow-up investigation, Goldman, Tarr, Pinchuk, and Kappler (1985) investigated the blood pressure effects of oscillating the body from upright to the fully inverted posture and back again. Each full cycle lasted at least 6 sec. Arterial blood pressure was measured after 5, 10, and 15 min of oscillation. Measurements were taken with the arm supported laterally at the heart level and the body completely inverted. SBP decreased upon inversion. Upright preinversion SBP was found to be $123 \pm 1.6$ mmHg. After 5 min of oscillation, it decreased significantly to $121 \pm 1.2$. The 10 min measurement revealed a SBP of $120 \pm 1.0$ mmHg and the 15 min measurement was $118 \pm 1.0$ mmHg. These authors suggested that the elevated BPs during static tilting may have resulted from the anxiety attendant with inversion. The ability to avoid a prolonged (static) inverted posture and the ability to control the degree and duration of inversion resulted in a relatively anxiety-free situation. In both this article and a letter written by these authors in the Western Journal of Medicine (1985), Klatz and associates modified their opinion of the safety of gravity inversion for healthy participants stating it was a safe activity for healthy individuals.

In a similar study, LeMarr, Golding and Crehan (1983) evaluated cardiorespiratory responses of 50 healthy young subjects who were tilted from the erect posture to -90$^{0}$ head-down position using a gravity oscillating device. Brachialblood pressure was measured with the arm in the anatomical position in the standing posture and alongside the head when inverted. Measurements were taken each min for 3 min per postural exposure. During inversion, SBP increased significantly and remained so until subjects were returned to the upright posture.

In an editorial on LeMarr's findings, Renfrew (1985) pointed out a likely source of measurement error in LeMarr's methodology. He stated, "The American Heart Association recommends that blood pressure be taken at heart level over the appropriate artery...I question whether a normal blood pressure can be assessed under these circumstances [those described by LeMarr and associates]." Golding replied that more discussion in the report should have centered on this procedure. He added that the arm position, in this study, should represent the blood pressure in the head and neck region.

An investigation by Kunkle, Hernandez, Johnson, and Baunann (1962) does not appear to support Golding's viewpoint. Kunkle, et al. wanted to find out if cranial vessels adapted to changes in blood pressure in the head-down position. Photoelectric devices placed on the skin quantitatively showed that some type of adaptive response occurred, but it did not indicate how it happened. Three reasonable hypotheses existed. The adaptive response could arise either from the stretch of veins or arteries or both. Changes in the size of large vessels in the face or scalp were not readily measurable, but fluctuations in the small vessels of the bulbar conjunctiva (located lateral to the medial canthus) were clearly visible under appropriate magnification and provided a suitable area for examination. The investigators used a binocular dissecting microscope in four subjects supine and then tilted them to $-50^0$ head-down. Through one ocular of this instrument photographs were made using a 35 mm camera with Tri-X film. In each tilt the veins were found to enlarge moderately; however, the arteries constricted slightly. This response was sustained for 2 to 3 min suggesting that, in the inverted posture, head vessels respond protectively to increased intravascular pressure by increasing arteriole constriction in the external carotid branches.

Relative to to Renfrew's (1985) criticism of LeMarr's methodology, the American Heart Association (1980) recommended a correction factor for BP values when the distal end of the cuff is not at heart level. They estimate that 1.8 mmHg should be added to the measurement for every inch the blood pressure cuff was positioned above the heart level. Conversely, the value of 1.8 must be subtracted from the reading for every inch below the heart level. The mean standing SBP in LeMarr and associates (1985) investigation was 113 mmHg. The SBP after the first min of inversion was found to be 139 mmHg. If this correction factor was applied to LeMarr's study, it would be conservatively estimated the blood pressure measurement was taken approximately 30 cm (12 inches) below the heart level. The adjusted SBP would be 118 mmHg. At the 2nd and 3rd min, SBP was even less significant (114 and 113 mmHg, respectively). Using these corrected values, the data of LeMarr and associates (1985) can be suggested as agreeing with previous investigations reporting no significant difference in SBP during head-down tilting. Although the American Heart Association recommended this correction factor, the adjustment appears to have been implied for the sitting and standing postures only.

A follow-up investigation by LeMarr, Golding, and Adler (1985) included an assessment of the effects of inversion on intraocular pressure and arterial blood pressure. Once again, these investigators reported significantly elevated SBP using the same arm position as in their previous study. They recommended that further investigations be done to examine arterial blood pressure response to tilting with the arm maintained in one position relative to the body in all postural exposures.

The BP effect of complete inversion in uncontrolled hypertensive subjects was investigated by Klatz, Goldman, Pinchuk, and Tarr (1985). Brachial arterial blood pressure changes were measured in these subjects over 3 min. The right arm was supported laterally at heart level for all measurements. Significant elevations were reported in mean SBP from 142 to 180 mmHg during inversion. Recommendations were made against prescribing gravity inversion boots to persons with uncontrolled hypertension.

## Diastolic Blood Pressure

The literature on DBP response to orthostatic stress was somewhat inconclusive. The earliest published report that was found on DBP was that published by Ellis (1921). The DBP generally increased from supine to $-45^{0}$ head-down, but the response was highly variable among subjects.

In Green and associates' (1948) investigation to find a clinical method to differentiate pathological tachycardia from tachycardia associated with excitement, the DBP was reported to have increased 16 mmHg. after tilt from +20$^0$ head-up to -45$^0$ head-down. However, after 20 sec, the DBP had returned to a level just slightly higher than in the starting position. The investigators attributed the increase in BP to the change in the hydrostatic force in the large arteries arising from the aortic arch. Throughout the excursion of the tilt, the arm was secured to an armboard perpendicular to the body. This enabled the arm to be maintained in a position in which the force of gravity on the column of blood within the arteries of the arm remained constant. The subsequent decrease in DBP was due to stimulation of the regulatory mechanism of the baroreceptors in the carotid sinus.

Wilkins and co-workers (1950) investigation on the acute circulatory effects of the head-down position in normal man revealed a dramatic drop in femoral artery DBP and less pronounced rise or no change in brachial artery DBP on tilting to -90$^0$. A gradual slight decline in DBP in both arteries was reported to have occurred after a few heart beats. A possible source of measurement error may be the position of the catheter sites in relationship to the manometer during the tilt.

Sancetta (1957) attempted to verify the findings of previous studies that an initial increase in brachial BP with head-down tilting is due to hydrostatics followed by baroceptor responses in the carotid sinus to counteract the increase in BP. Tilting to -35$^0$ produced an increase in the brachial DBP in all 10 subjects. Measurements were taken before and 15 min after tilting.

The investigation by Mengesha and Bell (1979) is one of the few studies that recorded various head-up tilts and head-down tilts. DBP showed little or no change in the head-up positions, but it increased significantly in the head-down positions (from 72 to 79 mmHg at $-30^0$ and 72-84 mmHg at $-60^0$). Blood pressure was measured using a sphygmomanometer and the arm was believed to be maintained next to the trunk on an armboard. Measurement was recorded 20-60 sec after tilting.

The methods described by Klatz and associates (1983) in their investigation on the effects of static inversion on systemic blood pressure required that the subjects grip a cross bar and then lift the legs over their heads to attach gravity boots to the bar to hang upside down. Diastolic BP was measured 45 sec and three min after initiation of the head-down tilt. DBP increased on inversion from $74 \pm 1.81$ to $93 \pm 1.93$ mmHg in the first 45 sec. After three min the DBP decreased insignificantly to $90 \pm 2.11$ mmHg. As previously mentioned, the arm was allowed to hang beside the head until the measurement was taken by investigator who held the right arm laterally at heart level. When the arms are hanging beside the head there is an increased hydrostatic venous pressure causing marked distension and pooling of the blood. Simultaneously, a marked increase in capillary pressure caused by the gravitational force of the blood produces increased filtration of fluid out of the capillaries into the interstitial space. The combined effects of venous pooling and increased capillary filtration may significantly increase peripheral resistance in the arms resulting in an increased DBP.

LeMarr and associates (1983) investigated the cardiorespiratory responses to inversion and revealed that DBP significantly increased initially and remained so during inversion. As previously mentioned, the inconsistency of measuring the blood pressure with the arm beside the trunk and then the head (approximately 30 cm below the heart) may account for this elevation as well as increased peripheral resistance due to inversion.

Oscillating inversion techniques were developed by Robert Martin, MD as a modality in his Decompression Mobilization Conditioning Program (DMT) (1985). Active oscillation is used frequently as an alternative to static inversion. It is performed by swinging the hands overhead to alter the center of gravity to move the occillator. As the hands move superiorly, the body is tilted to the head-down position. Goldman and associates (1985) felt it was prudent to determine the arterial blood pressure responses to this modality. Diastolic BP decreased upon assumption of static inversion after 5, 10, and 15 min of oscillation. They concluded that oscillating inversion did not produce any clinically significant change in DBP. The DBP response to passive oscillation may be different from active oscillation because of arm movement. During active oscillation, as in the forementioned article, the arms move repetitively from beside the torso to beside the head. The volume flow changes associated with this movement may significantly affect the DBP.

## The Heart Rate Effects of Postural Change With and Without Exercise

The original investigation on the effects of postural change on heart rate (HR) is purported to have been done by Y. Henderson and H. W. Haggard (1918). Measurements were taken in the erect, horizontal, and $-45^0$ head- down position using a tilting ballistocardiograph. They reported that HR decreased approximately 9.5 bt $\cdot$ $min^{-1}$ immediately upon tilting the body -45$^{o}$. An increase above baseline was observed when the body was tilted toward the head-up position.

Investigation of pulse rate response of men to passive postural changes that might be experienced by aviators was performed by M. M. Ellis (1921). From the horizontal and the standing position, the subject was inverted to -45$^{o}$. Measurements were taken immediately and after 5 min of tilting. He reported that preliminary tests in preliminary studies, HR leveled within the first 3 min of assuming the new postural position. As in the previous study, heart rate increased in the head-up position and decreased in the head-down position. Ninety percent of the 50 healthy young subjects' HR's decreased immediately on inversion. After 5 min, HR was still depressed in 86% of the subjects. The HR was 15 bt $\cdot$ min$^{-1}$ less initially in the standing versus the head-down posture; however, there was only 1 bt $\cdot$ min$^{-1}$ difference after 5 min.

Asmussen, Christensen and Nielsen (1940) investigated circulatory regulation mechanisms using one male subject with 60$^{o}$ head-up and head-down tilts. Since they found HR was reduced in the head-down position, they suggested baroreceptors in the carotid arteries of the neck had a higher pressure during head-down tilts, thus stimulating the baroreceptor reflex mechanism to reduce HR. Occulsion of blood flow to the lower extremities was performed prior to 60$^{o}$ head-up and head-down tilts to test the concept of a pressure governed carotid sinus. The reduction of HR in the inverted position and increase of HR in the upright position was significantly less remarkable with the blood flowed restricted. They concluded that controlling the amount of blood available to the major vessels from the lower extremity can alter the effect of tilting.

As noted in the previous section, H. S. Green and associates (1948) studied arterial blood pressure responses to -45$^0$ tilt. This testing was performed to develop a rapid method to differentiate tachycardia due to disease or drugs from tachycardia secondary to excitement. Heart rates, measured by electrocardiography, were obtained in one hundred subjects during tilting. Slowing of the heart rate invariably occurred during the 65$^0$ excursion from +20$^0$ to -45$^0$. In the majority of the cases, slowing was abrupt and resulted in bradycardia for a few beats which gradually subsided. The HR became relatively stable in every case within approximately 15 min. An acute increase in HR occcurred following the drop in arterial BP associated with the 65$^0$ excursion from -45$^0$ to +20$^0$. In all instances the rate was essentially the same as the original rate about 10 sec after the end of the tilt.

The effects of rapid movment (1 to 3 sec.) from the horizontal and erect to the 75$^0$ head-down tilt was examined by Wilkins, Bradley, and Friedland (1950). Forty-two subjects received catheters in the brachial and femoral arteries and the internal jugular vein. The arm remained alongside the body. Acute shoulder pain from the pressure of the shoulders bearing down on the shoulder braces of the tilt tables was reported. The affect on the individuals was so great that respiratory measurements were unable to be recorded. Increase HR with pain is well documented; however, a 32-46 bt $\cdot$ min$^{-1}$ reduction in HR was realized. Apparently the stimulus of the baroreceptors overruled the pain stimuli in regard to heart rate regulation.

Lawrence Lamb and James Roman (1961) from the School of Aerospace

Medicine, investigated the effect of rapidly changing from a positive G force tilt was accomplished. The HR then readjusted to a level most often just below the baseline HR. In all subjects the HR increased as the body was tilted back to the head-up position near or above the baseline values.

O. G. Gazenko and associates (1980) investigated central circulation and metabolism of 7 healthy men at rest, +70$^0$ and -30$^0$ tilt, and while performing arm exercise in the -30$^0$ head-down position. They observed an increase in HR upon assuming static +70$^0$ posture from 64 bt $\cdot$ min$^{-1}$ (supine) to 90 bt $\cdot$ min$^{-1}$. Tilting the subjects rapidly to -30$^0$ from +70$^0$ produced an immediate decrease in HR to approximately 59 bt $\cdot$ min$^{-1}$. After one hour, the HR had increased to approximately 62 bt $\cdot$ min$^{-1}$ (near pretest values). The investigators reported HR rose linearly with oxygen consumption during the use of arm crank ergometry at 100 kg $\cdot$ min$^{-1}$ for 7 minutes.

The autonomic control of the immediate heart rate response to lying down was inspected by F. Bellavere and D. J. Ewing (1982). Two groups of subjects were analyzed in 18 younger (23-26 years) and 10 older (48-67 years) normal subjects. HR was measured by electrocardiography. Immediate shortening of the R-R interval occurred when the act of lying down was initiated and in the second phase of this investigation, 6 subjects performed at standing to lying maneuver and then isometric handgripping (1 sec duration) in the standing, sitting, and supine postures. After muscular exercise, the R-R interval returns to the resting level after 10-15 beats and thereafter remains relatively constant. During the standing to lying maneuver, there is an additional lengthening of the R-R interval and a plateau occurs gradually.

In this study, atropine, a sympathetic blocker, was used to alter the HR response of eight healthy, young subjects. It abolished the initial shortening of the R-R interval associated with the act of lying down. It was concluded that the immediate part of the HR response to lying down (during the first 10 beats) is under vagal control and the latter is predominantly under sympathetic control. This conclusion concurs with Asmussen and co-workers (1940) observation of the baroreceptor response to increased blood flow suggesting HR and BP responses are inversely correlated and linear in relationship to degree of tilt.

Mechanisms of initial heart rate response to postural change were investigated by Borst, Wieling, VanBrederode, Hond, deRijk, and Donning (1982). Comparison was made between HR changes induced by free standing, and contraction of abdominal muscles and $+70^0$ tilt. The investigators concluded that immediate HR rise upon standing is associated with skeletal muscle contraction. A second rise in HR (from about 5-12 sec) and rapid decrease (between 12 and 20 sec) are associated with the fall, recovery, and overshoot of arterial blood pressure in the carotid sinus resulting from standing up. A gradual rise in HR was observed in $+70^0$ head-up tilt; however, contraction of the abdominal muscles with head-up tilt produced HR changes similar to that observed with standing.

The muscular effort of standing, it was said, probably activated both the exercise reflex and baroreceptor reflexes. The exercise reflex inhibits and the baroreceptor reflex enhances parasympathetic outflow to the heart. It must be realized, however, that baroreflex slowing of the heart is nullified during muscle contraction. This may be of significant interest in examination of HR and BP responses to $-90^0$ head-down tilt.

Klatz, Goldman, Pinchuk, Nelson, and Tarr (1983), studying the effects of gravity inversion procedures, reported a rise in pulse rate while in the inverted position. The heart rate was still elevated one min after resuming the upright posture. This appears to contradict previous investigations involving head-down tilt. However, the method used to invert the subjects was by having the subject lift the feet above the head using hip flexion and hooking a bar with Gravity Boots.[R] These boots have a hook allowing the subject to hang freely in the $-90^0$ position. The increased HR may be resultant of strong isotonic contractions of the hip flexors to hook the boots onto the stationary bar and emotional arousal from the unfamiliar concept of inversion.

LeMarr, Golding, and Adler (1984) used a gravity oscillating device to slowly and passively invert subjects to a free hanging position. HR was measured in the standing position, immediately and after each min of inversion for three min, then immediately and after one min upon reassuming the upright posture. HR response was in agreement with previous studies using the tilt table suggesting the greater the tilt, the greater will be the slowing of th e HR. HR decreased from approximately 84 $bt \cdot min^{-1}$ to approximately 68 $bt \cdot min^{-1}$ and remained stable throughout the inversion period. The HR increased to above baseline values post-tilt, but leveled within one min as reported to occur by Wald, Guernsey, and Scott (1937). The reduction in HR was attributed to normal baroreceptor response to increased pressure in the carotid sinus.

The effects of oscillating inversion on systemic blood pressure, intraocular pressure, and central retinal arterial presssure investigated by Goldman, Tarr, Anchuk, and Kappler (1985) included measurement of HR during oscillation between the upright and -90$^{0}$ inverted positions. Radial pulse rate was obtained after 5, 10, and 15 min of oscillation and measurements were taken in the inverted position. Mean HR prior to inversion was 69$\pm$1.8 bt $\cdot$ min$^{-1}$. At 5, 10, and 15 min, the HR was 66±1.9, 65$\pm$1.8 and 64$\pm$1.9 bt $\cdot$ min$^{-1}$, respectively. The decreases in HR from initial to five min and from 5 to 10 min were statistically significant. The difference between 10 and 15 min measurement times were not statistically significant. These investigations concluded that this response is reflex mediated due to increased venous return.

The recent investigation by Klatz, Goldman, Pinchuk, and Tarr (1985) on the effects of static -90$^{0}$ gravity inversion on hypertensive subjects, revealed significant increases in HR. HR increased from 80±4 bt $\cdot$ min$^{-1}$ in the preinversion "seated" posture to 106±6.5 bt $\cdot$ min$^{-1}$ in the inverted posture. These investigators cited previous studies demonstrating that the baroreceptor reflexes prevent a rise in arterial blood pressure which may include a reduction in HR and total peripheral resistance. Investigations on tilts greater than -45$^{0}$ reveal a decrease in HR is consistently observed in both normal and tachycardic subjects. Klatz and associates suggested the reason for the increase in HR in tilts of this magnitude was due to another mechanism other than increased venous return and cited anxiety and psychological adjustment to inversion procedures even more than with a tilt table. It is interesting to note that these investigations are the only ones to use the gravity inversion boots hooked on a bar. The subjects are required to lift their feet to the bar over their head to hook the bar. This requires a substantial amount of isotonic hip flexion by the subject. The work, combined with the psychological factors and additional preload may be responsible for the significantly high heart rate.

The Oxygen Consumption Effects of Postural Change at Rest and During Exercise

Previous investigations on the oxygen consumption ($\dot{V}O_2$) effects of postural change have predominantly been performed to examine pulmonary responses to aerospace flight.

McMichael (1937) investigated postural changes in cardiac output and respiration in man. $\dot{V}O_2$ was measured when subjects were moved from the supine to an upright position on a mattress fixed to a board. A reduction in $\dot{V}O_2$ was observed shortly after the subjects were moved to the upright position. Upon resumption of the supine posture, a transient increase in $\dot{V}O_2$ was noted.

Sancetta (1956) desired to study the $\dot{V}O_2$ effects of a sustained -35$^{o}$ tilt. Baseline measurements were obtained in the supine posture. Each was then tilted on a motor-driven fluoroscopy table to -35$^{o}$. Measurement was repeated after 15 min in this position. Control measurements were done in duplicate and required to vary less than 10% from each other to be accepted as valid. No significant difference in $\dot{V}O_2$ was observed.

Loeppky and Luft (1975) investigated the effects of changes in posture on oxygen transfer at the mouth and pulmonary capillary membrane to observe concomitant subtle changes in ventiliation at rest. Thus, it was the objective of these investigators to examine the time course of $\dot{V}O_2$ changes with passive postural change. Six subjects were tilted from supine to +60$^o$. Measurements were performed before, during, and after passive tilt, and on return to recumbancy after 10 min in the erect posture. Tilting to the +60$^o$ posture resulted in an immediate rise in $\dot{V}O_2$. A decrease in $\dot{V}O_2$ was observed after 30 sec in the upright posture and showed marked fluctuations. Ten min after the recumbent position was resumed, $\dot{V}O_2$ decreased momentarily below baseline. However, at 35 sec., it began to rapidly increase and returned near baseline after 90 sec.

Meatlon and Farhi (1979) examined $\dot{V}O_2$ changes in head-up tilts to +90$^o$ from supine on five healthy laboratory employees. Measurements on any one subject were measured at tilt angles varying from 0$^o$ to +90$^o$ in 15$^o$ increments. All measurements were preceeded and followed by measurements at baseline supine. $\dot{V}O_2$ did not vary as long as the tilt angle remained low but increased between +75$^o$ and +90$^o$. At this point there was a significant increase in $\dot{V}O_2$. These investigators attributed this increase on the autonomic nervous system response involving increased excretion of epinephrine.

O. G. Gazenko and associates (1980) examined $\dot{V}O_2$ response in 7 healthy male subjects during postural exposures and arm exercise (100 kg min$^{-1}$) for seven min in the head-down posture. Baseline $\dot{V}O_2$ was measured in the supine posture. No significant change was observed from passively tilting the subjects to the +70$^o$ tilt and then to the -30$^o$ tilt. However, $\dot{V}O_2$ increased significantly when arm exercise was performed. It was noted that $\dot{V}O_2$ increased linearly with increases in HR and somewhat linearly with increased metabolic acidosis and hyperventilation.

Summary

This section was a presentation of a review of previous investigations on the hemodynamic and metabolic effects of orthostatic stress. The parameters of SBP, DBP, MAP, HR, and $\dot{V}O_2$ were examined. Early investigations on the hemodynamic and metabolic effects of postural change were performed to examine what occurs during syncope and aerospace flight. Recent investigations have been performed for space shuttle missions and to examine the possible detrimental effects of inversion when used for recreational or therapeutic purposes. The results obtained by these investigators are quite dependent on the method of tilting the individual to the posture to be examined (i.e., active versus passive tilting, use of motor driven tilt-table versus ankle boots versus ankle boots and oscillator). Brachial arterial blood pressure varied according to arm position during postural exposure as well. Generally speaking, SBP increased with tilts to the head-down posture when the site of measurement was anatomically above the heart level. Brachial SBP decreases somewhat linearly with tilts in the head-up posture when the measurement is performed superiorly to heart level. DBP varied somewhat in its response to head-up and head-down tilts. Little to no change in DBP occurred when the body was tilted to the head-up posture. However, the majority of the investigations revealed significant increases in DBP during head-down tilts. Heart rate (HR) responded somewhat in a linear fashion with the degree of tilt in most of the investigations. HR increased with head-up tilts and decreased with head-down tilts. Most investigators attributed the change to be associated with the pressor receptors in the carotid sinus. Finally, oxygen consumption ($\dot{V}O_2$) responses to passive tilting were inconsistent.Reasons for the changes in $\dot{V}O_2$ were varied; however, there appears to be some agreement between investigators that increases in the $\dot{V}O_2$ during head-down tilt may be attributed to stimulation of autonomic nervous system responses and muscle contraction to compensate for the discomfort of inversion.

# CHAPTER III

## Manuscript

The prevalence of low back pain is widespread, affecting 80% of all people (1). The National Center for Health Statistic's National Hospital Survey reports that 149,000 people in the United States underwent diskectomies (surgical removal of the disk) in one recent year (1). One alternative treatment for low back pain used in recent years is inversion therapy (i.e., total inversion of the body to $-90^0$ head-down tilt). Advocates claim that decompression of the spine provides relief to the low back pain sufferer (12). To accomplish spinal decompression using inversion, "gravity boots" have been designed. The boots are actually ankle cuffs that hook onto a bar, allowing the subject to mount a frame and be tilted into the head-down posture actively or passively while being suspended by the ankles (Figure 1).

[Place Figure 1 about here.]

Questions were raised in 1983 about the cardiovascular safety of inversion therapy. Two groups of researchers (7,9) reported significant increases in brachial arterial blood pressure over a 3 min bout of static $-90^0$ head-down tilt. Health professionals were cautioned against recommending inversion as a practical mode of back pain treatment or for recreational exercise until further research could be performed on the effects of exercise in the inverted posture. Therefore, the purpose of the present investigation was to further delineate the effect of inversion at rest and inversion coupled with exercise upon metabolic and hemodynamic responses.

METHODS

Subjects. Eleven male volunteers were included in this study. The mean age was 21.1 ± 1.3 yr. Descriptive data are presented in Table 1. Preliminary screening of prospective participants ensured that each subject was "apparently" healthy and possessed a fitness level adequate for performance of the exercise tasks and postural stress. Furthermore, this screening served to provide a homogenous sample in terms of physical training, percent body fat, familiarity to inversion techniques, tolerance to orthostatic stress, and it also provided opportunity to minimize subject anxiety and learning effects which might contribute to extraneous variability in the dependent measures.

[Place Table 1 about here]

Experimental Conditions and Design. The subject participated in six experimental sessions on a gravity oscillator(Gravity Guidance, Inc. Model 1121). During testing, ambient temperature was maintained between 22.5 - 26.5°C. Subjects were asked to refrain from vigorous activity on the days of their sessions and the serial testing was done at the same time of day. Subjects proceeded through an order of sesions as listed in Table 2. The order of exposure to postural conditions was counter balanced(i.e., inverted versus supine) for the hemodynamic sessions. The sessions were separated by at least 36 hours.

[Place Table 2 about here]

The duration of each postural trial within each testing session was 3 minutes. To ensure that the arms would be kept in the same anatomical position (alongside the torso) throughout the testing, a non-constricting rope loop was placed around each wrist and secured to the oscillator. The subject was instructed not to ense his arm muscles in order to maintain the position, but rather to let them hang limp from the ropes. All metabolic and hemodynamic measuremnents were taken in the supine, standing, and inverted postures. Hemodynamic measurements were also taken in the seated posture during the equilibration periods which were interposed between trials(Figure 2). Each subject was seated upon the oscillator as depicted in Figure 1a for 15 minutes prior to the first postural exposure. Subsequent equilibration periods of 5-8 minutes occurred after the second and third postural exposures. In the sessions where exercise was coupled with postural stress, a metronome was used to pace hip-flexion activity to 45°(hip-flexion measured by goniometry). Discontinuous exercise was performed over the first thirty seconds of each minute in each posture by repeatedly flexing the hips to 45°. For the metabolic analysis, the number of hip-flexions was held to 7 in all postures. This was done to enable the investigator to control the joint angle and reduce substitution by other muscle groups. The number of repetitions was adjusted to equate the workload in the least demanding to the most demanding for the hemodynamic sessions. No exercise was performed during the remaining thirty seconds of each minute.

Metabolic Measurements. The metabolic analysis was performed during each subject's first two sessions. Oxygen consumption($\dot{V}O_2$) measurements were performed during the last minute of each postural exposure. There were two reasons for performing the metabolic measurements in trials that were separate from those in which the hemodynamic measurements were taken:

1. It was desired not to have to account for the weight and awkwardness of the mouthpiece, head harness, and hoses of the gas analysis system during the hemodynamic investigation.
2. It was also desired to adjust the workload for the two least demanding postural plus exercise trials (by increasing hip-flexion repetitions) to "rule out" the metabolic response to varying work during the hemodynamic investigation.

To measure $\dot{V}O_2$, the investigator fitted the individual with an appropriate mouthpiece and head harness. Minute ventilation volume(expired air, $\dot{V}_E$) was determined using a Hewlett-Packard Pneumotach(Model A-7303A). Oxygen content of the dry expired air was determined using a Rapid Response Applied Electrochemistry Oxygen Analyzer (Model CDE-3AAA). Oxygen and carbon dioxide content of the expired gas and the volume of air ventilated was recorded the third minute of each postural exposure.

Hemodynamic Measurements. Hemodynamic responses were assessed in the last four sessions. Data from the metabolic investigation provided the means for equating the $\dot{V}O_2$ requirement for each subject's three exercise plus posture combination. It was determined that 45° hip flexion in the inverted posture consumed 7% and 36.5% more oxygen than in the supine and standing postures, respectfully. Therefore, the number of repetitions in the supine posture was increased by one, while the number was increased by three in the standing posture. Heart rate and blood pressure was measured after three minutes in both the non-exercise and exercise trials.

Heart rate was measured electrocardiographically and indirect systolic and diastolic pressure was assessed over the left arm using a DINAMAP™ Adult/Pediatric Vital Signs Monitor(Model 845XT) from Critikon, Inc. Measurement was performed non-invasively using the oscillometric technique as has been previously described(14).

Results. Statistical analysis of the hemodynamic measures in equilibration was performed to ensure the body had readjusted to the sitting posture. A repeated measures analysis of variance procedure resulted in F-values for HR, SBP, and DBP of 6.50, 3.38, and 4.59, respectively, none of which revealed any statistically significant difference($p > .05$) between the equilibration periods in any of the parameters examined. The actual levels of significance were .57, .52, .39, and .71, respectively.

Since all subjects proceeded through sessions one through six in the same order, it was suspected that an ordering effect might have occurred. To analyze the data to make sure this did not occur, the investigators totaled the third minute responses for each of the hemodynamic parameters according to the order in which each session occurred(Table 2). The statistical analysis was designed so as to examine the effects of mode (exercise versus non-exercise), ordering (the progression of various tilts), and the interaction of mode and order. The repeated measuresa ANOVA resulted in F-values for HR, SBP, and DBP equal to 3.67, 4.85, and

1.96, respectively.

After the analysis on the equilibration and ordering effects was completed , the analysis on the effects of posture was performed. The following is a description of the statistical analysis of each of the parameters as related to exercise and non-exercise in the supine, standing, and inverted postures.

For the variable of oxygen consumption($\dot{V}O_2$), the repeated measures ANOVA revealed no significant effect relative to body position($F=3.6;df=2,10;p>.05$). However, a significant difference was observed between rest and exercise in the various positions($F = 20.93$; $df = 1,10$, $p<.05$). Examination of rest versus exercise in Figure 3 illustrates the significant increase in ($\dot{V}O_2$) during exercise.

[ Place Figure 3 about here]

For the variable of heart rate, a repeated measures ANOVA procedure was employed to analyze the third minute heart rate responses to posture, mode, and the interaction of posture and mode. Heart rate response to rest and exercise during postural exposure are graphically illustrated in Figure 4. Body position was found to significantly affect heart rate during each minute of postural exposure($F=7.79;df=2,10;p<.05$). The Tukey Studentized (HSD) Range Test revealed that the posture-related variation in HR was attributable to significantly higher vaues in the standing posture($\overline{x}$ = 89.6 and 90.5 beats per minute for rest and exercise, respectively). No significant difference in HR was found in relation to rest and exercise; however, this may be attributed to a 30 second rest period prior to the measurement of the HR response.

[ Place Figure 4 about here]

The inclusion of exercise significantly elevated SBP ($F = 45.65; df = 1,10; p < .05$). The Tukey procedure revealed that the mean exercise SBP was 128.4 which was significantly greater than the non-exercise mean SBP of 118.8(Figure 5). [ Place Figure 5 about here]

Both postural and exercise factors significantly affected the diastolic blood pressure, (i.e., F = 18.3 and 8.1; $p < .05$). Subsequent post-hoc analysis showed that supine resting DBP was significantly lower than for the other two resting postures ( Tukey procedure, $p < .05$) (Figure 6). The analysis revealed a significant increase in DBP in the standing posture.

[Place Figure 6 about here]

# DISCUSSION

The concept of using inversion to decompress the spine has gained rapid success in recent years which is indicated by manufacturer's claims that over 1 million inversion systems have been sold. However, one must consider the indication, contraindications, and side effects encountered when prescribing any therapeutic modality. It was the purpose of this investigation to determine hemodynamic and/or metabolic responses associated with inversion of the body at rest and with exercise.

The first objective of this study was to determine if there was any difference in the amount of oxygen consumed at rest and during exercise in the inverted posture (hanging) versus the supine and standing postures. Under non-exercising conditions, no significant difference was found between $\dot{V}O_2$ at rest in the inverted posture or the standing posture. This finding disagrees with those observed by McMichael(13) and Loeppky and Luft(11) in demonstrating $\dot{V}O_2$ decreased when tilted to the upright posture. The $\dot{V}O_2$ during passive -90° head-down tilt was only 1.7% greater than in the standing and supine postures, respectively. During exercise, $\dot{V}O_2$ in the inverted posture was 7% and 36.5% greater than in the supine and standing postures, respectively.

The second objective of this study was to determine if there were any differences in heart rate and blood pressure responses attributable to exercise, posture or the combination of these two stressors. The observed heart rate response to passive inversion (rest) disagrees with the results of Klatz and associates (8,9) and showing that responses in the inverted posture were usually higher than in other positions when the baseline posture was sitting (Figure 4). Klatz and associates contend that emotional and psychologic factors could have contributed to the observed increases in HR which they observed, thus implicating a sympathetic nervous system response not caused by the postural shifts. Katkov and associates (7) reported heart rate increased with increased shifting of blood toward the head with -20$^{0}$ head-down tilt for 3 hours. The sympathetic response (anxiety, vestibular stimulation, etc.), appeared to dampen the anticipated decrease in heart rate associated with increased baroreceptor stimulation (increase in pressure in the carotid sinus which causes activation of the cardioinhibitor center - parasympathetic). This response appeared to occur more readily when sitting was the baseline posture. Other investigators, such as LeMarr and associates (10), reported reductions in HR when the individual was shifted from the supine to the head-down posture.

The heart rate response to exercise in various postures appears to follow the pattern for the resting conditions, but the heart rates for the supine and inverted exercise was faster which again may illustrate diminished barorecptor stmiulation.(Figure 4). These results coincide with the findings of Gazenko and associates (3); they evaluated the postural effects of central circulation and metabolism in man during arm exercise in the -30$^{0}$ head-down posture. In these subjects, heart rate increased significantly over values observed in the -30$^{0}$ posture without exercise. They interpreted that the sympathetic nervous system stimulation coupled with the increased workload required to perform inverted hip-flexion exercise may interact to dampen the baroreceptor responses, thus resulting in an increased heart rate.

The statistical analysis of the BP responses to postural stress revealed in the current study no interaction between mode (non-exercise vs exercise) and posture (Figure 5). This indicated that for SBP and DBP, the responses were the same except that the BP values during exercise were greater than those at rest. This appears to be consistent with the normal blood pressure response to exercise resulting from increased cardiac output and decreased peripheral resistance caused by vasodilation of the microcirculation.

Blood pressure effects of inversion have been somewhat uncertain, based on the findings reported in the previous literature (10). A possible reason for this is inconsistency of arm position. LeMarr and associates (10) measured blood pressure with the arms hanging in a gravity-dependent position beside the head during inversion. However, the baseline (sitting) BP measurement was taken with the arm beside the torso. Klatz and associates (20) also allowed the arms to hang beside the head during inversion until BP measurement time. At that point, the arm was abducted from the body. Significant increases in SBP and DBP were also observed.

In the present investigation, both arms were maintained in the anatomical position by using nonconstricting rope loops around each wrist. Since the arm position and BP cuff were placed such that the measurement locus of the brachial artery was at heart level, the blood volume changes would also affect the results of the measurement. It is reasonable to assume that the height of a column of blood (brachial artery) will have a significant effect on the pressure being exerted upon it. Therefore, when the arms are hanging beside the head in the inverted posture, the column height is much greater than when the arms are positioned beside the torso in the sitting, standing, or supine postures.

This investigator has not found any previous investigations on the circulatory effects of $-90^{0}$ head-down tilt in which the arms were maintained in the same position throughout the testing. This investigation provides data which support those findings in earlier investigations where SBP had not significantly increased in the head-down posture or had initially increased and subsequently decreased within a 3 min period (4,5). Rate-pressure product (DP) can be used as an index of myocardial oxygen demand. LeMarr's (10) investigation of BP responses to inversion with the arms hanging beside the head revealed a 3 min inverted DP of 92 which is greater than found in this investigation ($\bar{x}$ = 79.36).

Measurement of brachial diastolic BP in the inverted posture with the arms hanging beside the head would naturally yield higher value if the arms were beside the torso due to the pooling of blood in the arms. In an editorial on LeMarr's findings, R.A. Renfrew (15) pointed out a likely source of measurement error in LeMarr's methodology. He stated, "The American Heart Association recommends that blood pressure be taken at least level over the appropriate artery... I question whether a normal blood pressure can be assesed under these circumstances (those described by LeMarr and Associates)." Golding replied that the arm position, in LaMarr's study, should represent the blood pressure in the head and neck region. However, other published findings (6) illustrate that protection from brain hemorrhage may be afforded by the concomittant increase in cerebrospinal fluid. It was also pointed out that the skull provides a closed cage which restricts the continual effusion of blood into the blood vessels of the head. One plausible reason for the feeling of pressure and fullness in the head and face is that there are no valves to the veins superior to the heart level. Therefore, in the inverted posture, the blood must return to the heart by skeletal muscle contraction and systolic pressure.

Finally, LaMarr (10) and Sheppard (16) recommended that exercise in the inverted posture be avoided until further research is completed. This investigation illustrates that 45° hip-flexion activity by no means increased blood pressure to the level reported by Carswell (2). Carswell reported the blood pressure response in extensive weight training showed measurements of 450/310 mmHg. Further investigations on the blood pressure response to various exercise in the head-down posture and inversion of subjects suffering hypertension is recommended.

References

1. American Medical Association. _The American Medical Association Guide to Backcare - Revised and Updated Edition_, 1984.

2. Carswell, H. Even for experienced lifters, overdoing it can pose a threat. _Medical Tribune_.

3. Gazenko, O.G., V.I. Shumakov, L.I., Kakurin, V.E. Katkov, V.V. Chestukhin, V. M. Mikhailov, A.Z. Troshin, and V.N. Nesvestov. Central circulation and metabolism of the healthy man during postural exposures and arm exercise in the head-down position. Aviat Space Environ. Med. 51(2):113-120,1980.

4. Green, R. S., A. Iglauer, and J. McGuire. Alternations of radical or brachial intra-arterial blood pressure and of the electrocardiogram induced by tilting. _J_. Labs _Clin_. _Med_. 33:951-960, 1948.

5. Henderson, Y. and H. N. Haggard. T. The circulation in man in the head-down position, and a method for measuring venous return to the heart. _J_. _Pharmacol_. _Experi_. _Therap_. 11:189-201, 1918.

6. Henry, J.P., The Physiology of Negative Acceleration. Wright-Patterson Air Force Base Report(TR 5953)., 1950.

7. Katkov, V. E., V. V. Chestukhin, R. I., Lapteva, V. A. Yakovleva, V. M. Mikhailov, O. K. Zybin, and V. N. Vtkin. Central and cerebral hemodynamics of the healthy man during head-down tilting. Avait. Space Environ. Med. 50(2):147-153, 1979.

8. Klatz, R. M., R. M. Goldman, B. G. Pinchuk, E. E. Nelson, R. S. Tarr. The effects of gravity inversion procedures on systemic blood pressure. J. Am. Osteopath Assoc. 82(7):853-857, 1983.

9. Klatz, R. M., R. M. Goldman, B. G. Pinchuk, R. S. Tarr. Effects of gravity inversion on hypertensive subjects. The Physician and Sports Medicine. 13(3):85-89, March, 1985.

10. LeMarr, J. D., L. A. Golding and J. G. Adler. Intraocular pressure response to inversion. Amer. J. Opthal. and Physiol. Optics. 61(11):679-682, 1984.

11. Leoppky, J. A. and U. C. Luft. Fluctuations in oxygen stores and gas exchange with passive changes in posture. J. Appl. Physiol. 39:47-53, 1975.

12. Martin, R.M., II DMT: Decompression Mobilization Therapy, Gravity Guidance, Duarte, Ca., 1985.

13. McMichael, J. Quart. J. Exptl. Physiol. 27:55, 1937.

14. Ramsey, M. Non-invasive asutomatic determination of mean arterial pressure. Med Biol Eng Compt. 17:11-18,1979.

15. Renfrew, R.A.(ed.)Inversion and blood pressure. The Physician and Sports Medicine. 12(2):15,1984.

16. Sheppard, R.J.(ed), Cardiorespiratory responses to inversion. Sports Medicine. 1983.

17. Wilkins, R. W., S. E. Bradley and C. K. Friedland. The acute circulatory effects of the head-down position (negative G) in normal man, with a note on some measures designed to relieve cranial congestion in this position. J. Clin. Investigation. 29:940-949, 1950.

Table 1. Subject Characteristics .

| | | |
|---|---|---|
| Age | 21.1 | ±.39 |
| Height | 177.2 | ±.93 |
| Weight(kg) | 72.7 | ±1.7 |
| Body Fat(%) | 10.7 | ±1.27 |

Symbols are mean(x) and standard error of the mean(SEM).

Table 2. Schema for Various Sessions of Postural Exposure and the Type of Parameters Examined During Each Session.

| Condition Session | Physiological Parameters Examined | Time | 1<br>15 min | 2<br>3 min | 3<br>5-8 min | 4<br>3 min | 5<br>5-8 min | 6<br>3 min |
|---|---|---|---|---|---|---|---|---|
| 1 | M | | EQ | SUN | EQ | STN | EQ | IN |
| 2 | M | | EQ | SUE | EQ | STE | EQ | IE |
| 3 | H | | EQ | SUN | EQ | STN | EQ | IN |
| 4 | H | | EQ | SUN | EQ | IN | EQ | STN |
| 5 | H | | EQ | SUE | EQ | STE | EQ | IE |
| 6 | H | | EQ | SUE | EQ | IE | EQ | STE |

M = Metabolic

H = Hemodynamic

E = 45$^{o}$ Hip-flexion Exercise

EQ = Sitting Rest

SUN = Supine Nonexercise

SUE = Supine 45$^{o}$ Hip-flexion Exercise

STN = Standing Nonexercise

IN = Inverted Nonexercise

STE = Standing 45$^{o}$ Hip-flexion Exercise

IE = Inverted 45$^{o}$ Hip-flexion Exercise

Figure 1. Photograph of subject on the gravity oscillator in the inverted posture.

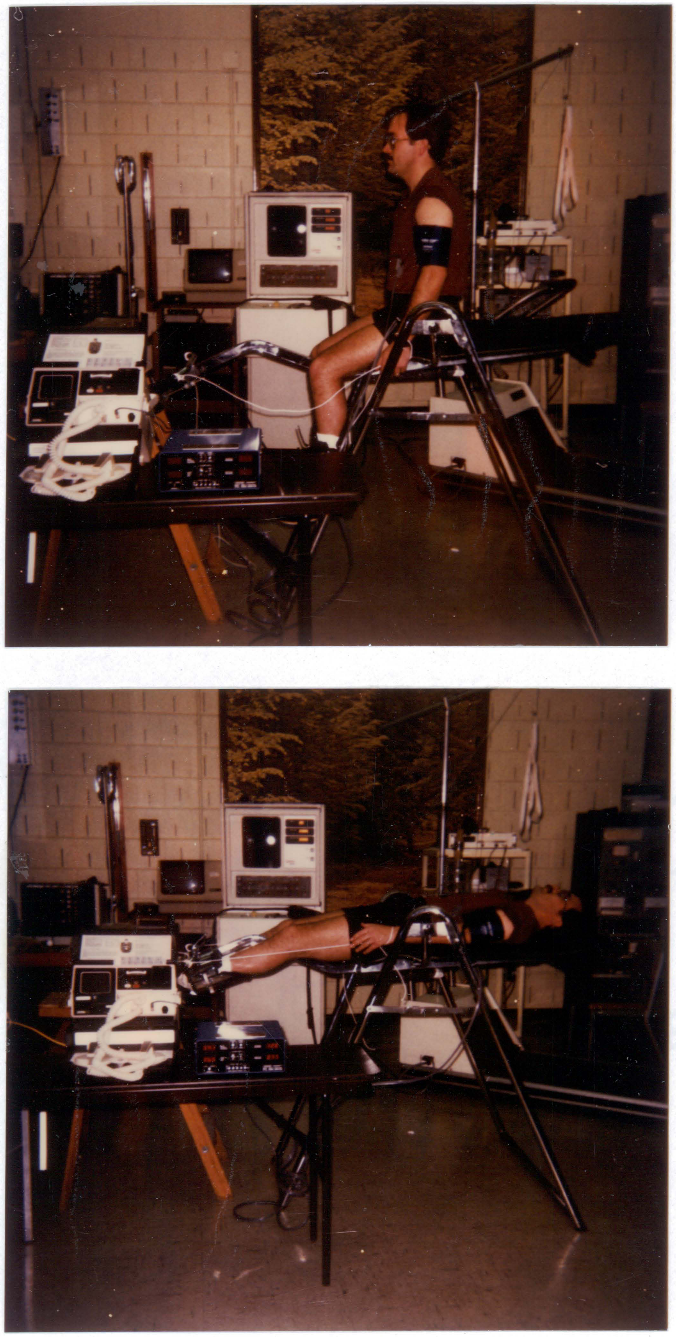

Figure 2. Photographs of subjects in the sitting and supine postures on the gravity oscillator.

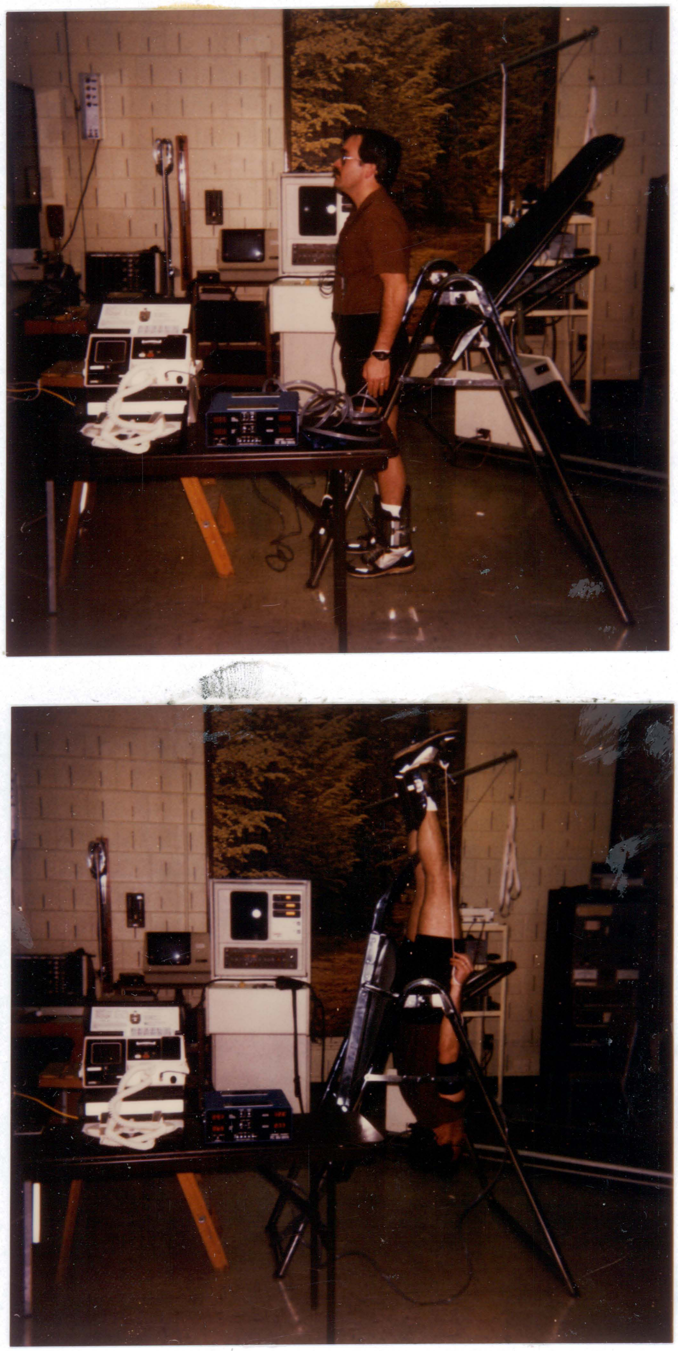

Figure 3. Photographs of subjects in the standing and inverted posture on the gravity oscillator.

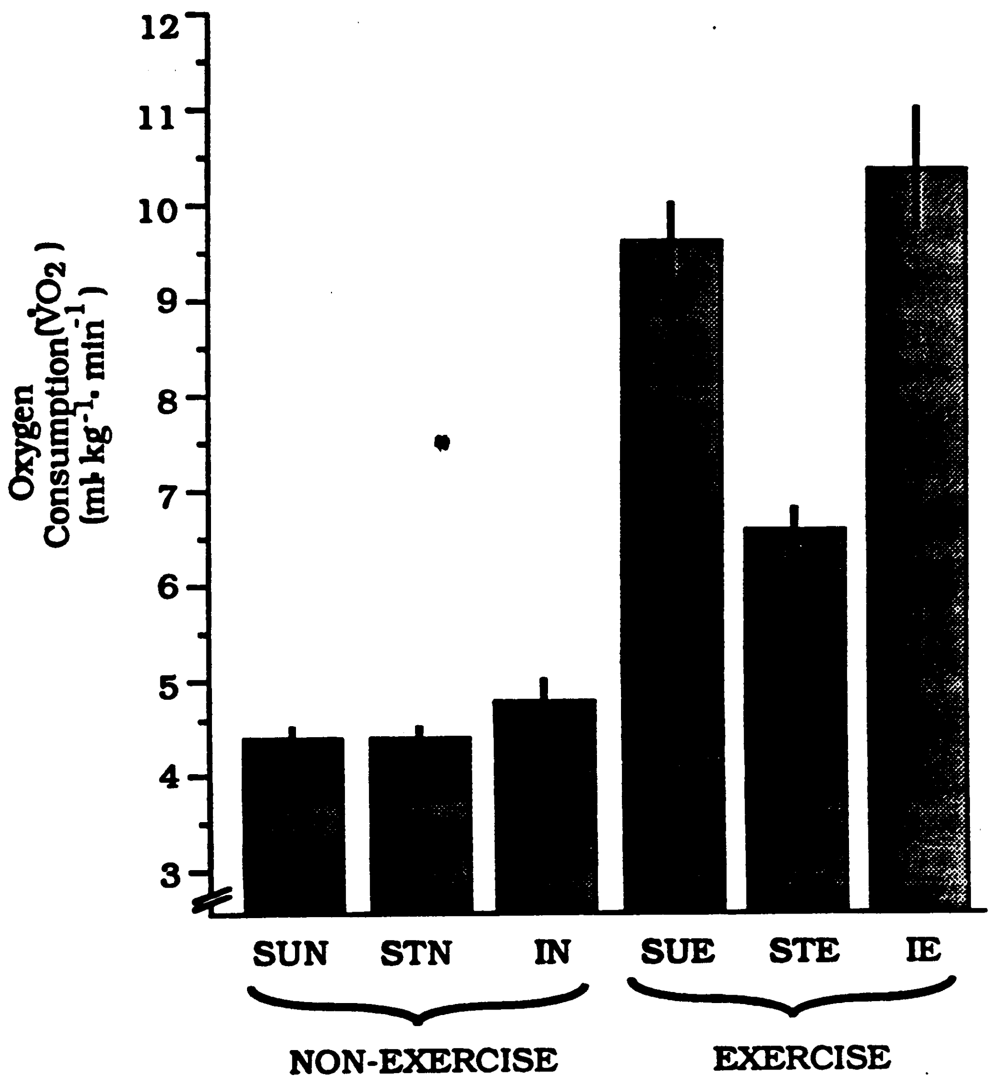


**FIGURE 3:** Graph depicting oxygen consumption ($\dot{V}O_2$) at rest and exercise in each posture (supine, standing, and inverted) after 3 minutes duration.

SUN = Supine Non-Exercise
STN = Stand Non-Exercise
IN = Inverted Non-Exercise

SUE = Supine Exercise
STE = Stand Exercise
IE = Inverted Exercise

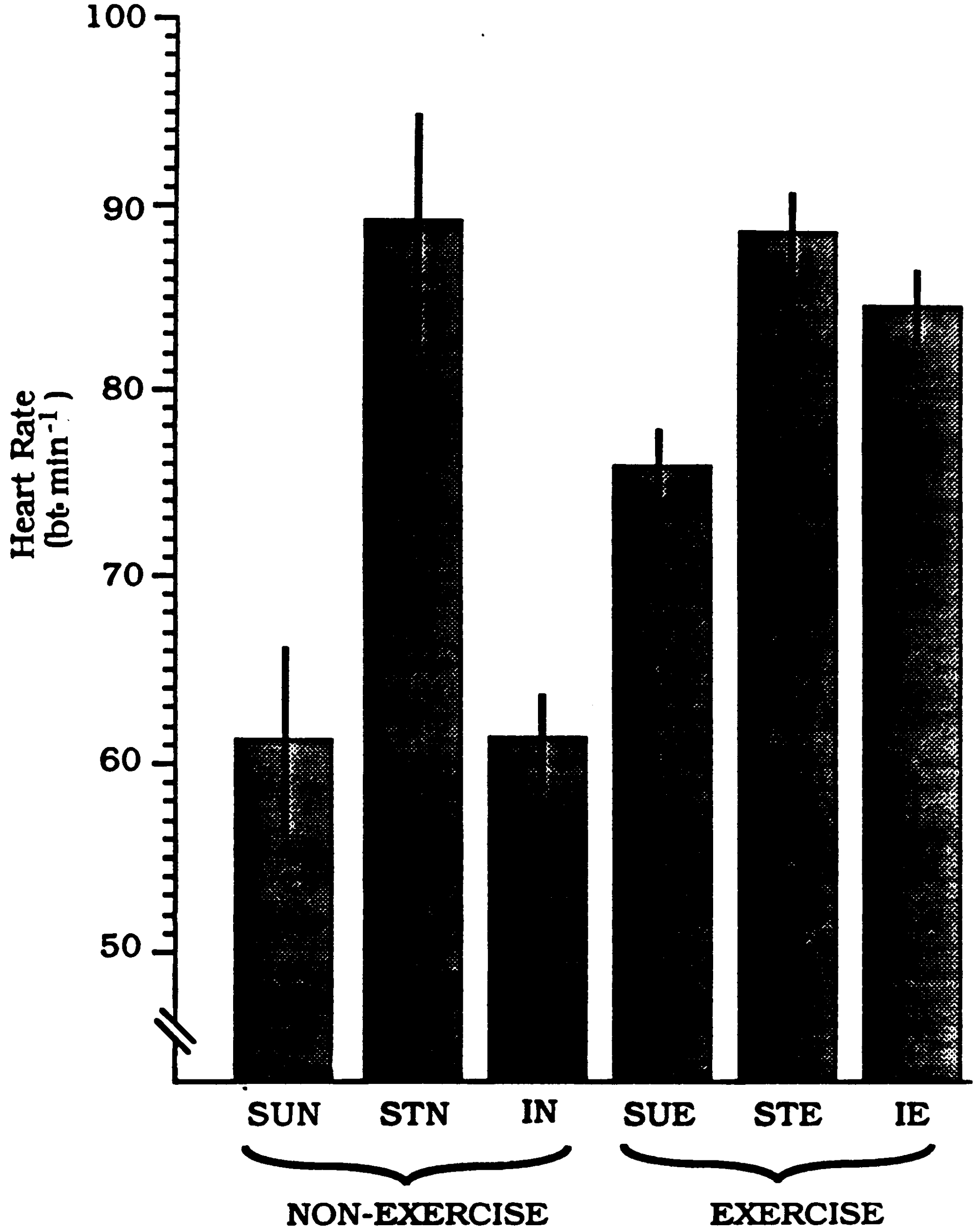


Figure 4: Graph depicting heart rate (bt·min$^{-1}$) at rest and exercise in each posture (supine, standing, and inverted) after 3 minutes duration.

SUN = Supine Non-Exercise
STN = Stand Non-Exercise
IN = Inverted Non-Exercise

SUE = Supine Exercise
STE = Stand Exercise
IE = Inverted Exercise

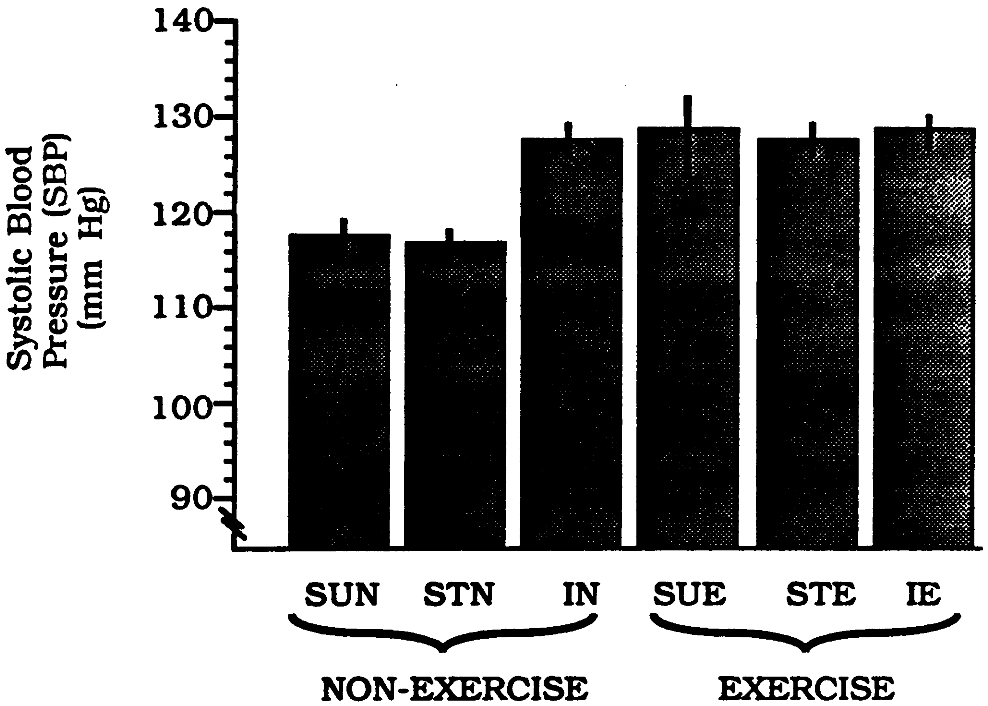


**FIGURE 5: Graph depicting systolic blood pressure (SBP) at rest and exercise in each posture (supine, standing, and inverted) after 3 minutes duration.**

**SUN = Supine Non-Exercise**
**STN = Stand Non-Exercise**
**IN = Inverted Non-Exercise**

**SUE = Supine Exercise**
**STE = Stand Exercise**
**IE = Inverted Exercise**

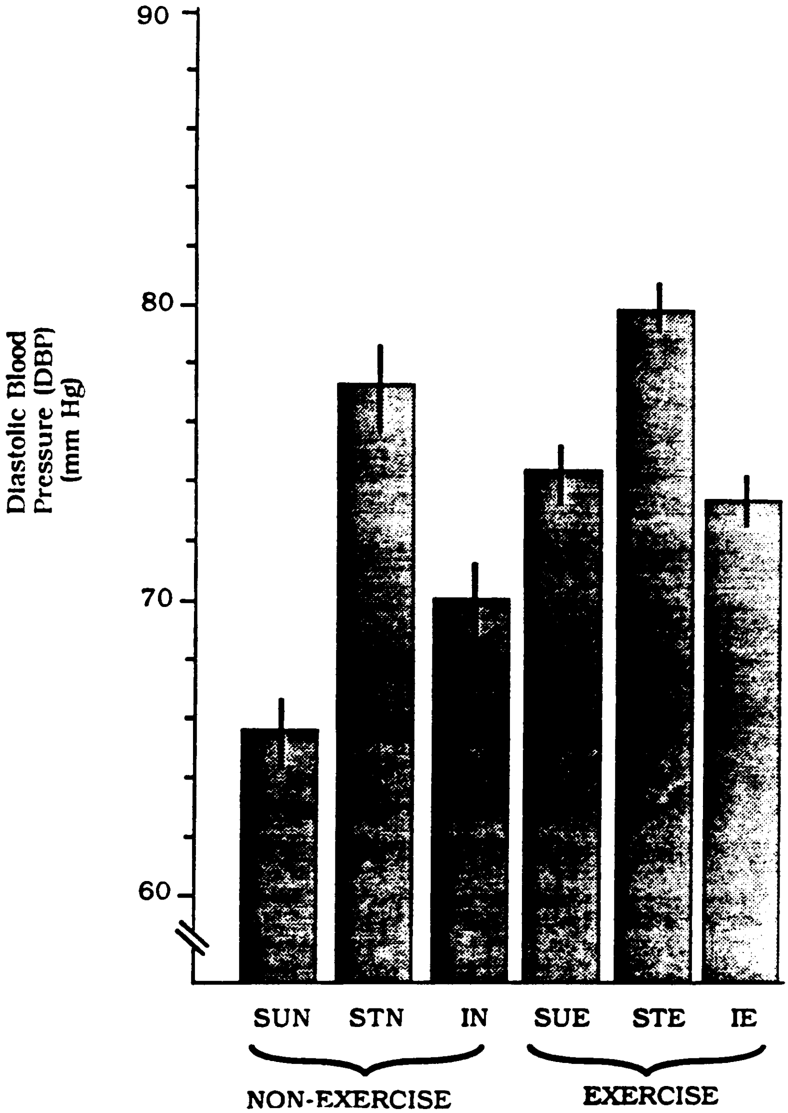


FIGURE 6: Graph depicting diastolic blood pressure (DBP) at rest and exercise in each posture (supine, standing, and inverted) after 3 minutes duration.

SUN = Supine Non-Exercise
STN = Stand Non-Exercise
IN = Inverted Non-Exercise

SUE = Supine Exercise
STE = Stand Exercise
IE = Inverted Exercise

# Chapter IV

## Summary and Recommendations for Future Research

### Summary

The prevalence of low back pain is widespread, affecting 80% of all people (American Medical Association, 1984). The National Center for Health Statistic's National Hospital Discharge Survey reports that 149,000 people in the United States underwent diskectomies (surgical removal of the disk) in one recent year (American Medical Association, 1984). One alternative treatment for low back pain used in recent years is inversion therapy (i.e., total inversion of the body to $-90^{0}$ head-down tilt). Advocates claim that the decompression of the spine provides relief to the low back pain sufferer. To accomplish spinal decompression using inversion, gravity boots have been designed. The boots are actually ankle cuffs that hook onto a bar, allowing the subject to mount a frame and be tilted into the head-down posture.

Two groups of researchers (21,26) raised questions about the safety of inversion when they reported significant increases in brachial arterial blood pressure over a three minute bout of static $-90^{0}$ head-down tilt. Health professionals were cautioned against recommending inversion as a practical mode of treatment for therapeutic purposes or as exercise for recreational purposes until further research was performed to evaluate the potential for acute detrimental effects on the cardiovascular system.

Recently, Goldman et al. (13) reported a significant lowering of BP when oscillating the body from upright to the fully inverted posture over periods of 5, 10, and 15 min. Although static inversion has been shown to precipitate a significant increase in BP, oscillating inversion appears to lower BP significantly. Based on previous physiological investigations, the present study was undertaken to further deliniate the effects of inversion at rest and coupled with exercise upon metabolic and hemodynamic parameters.

Eleven adult male subjects of similar physical fitness levels volunteered and gave consent. Submaximal exercise testing (85% predicted heart rate maximum) was performed using bicycle ergometry to evaluate the level of fitness of each participant. Each subject was oriented to the equipment and was allowed to become comfortable with the technique of inversion.

The study consisted of three sessions of passive tilting and three sessions of exercise plus postural stress. Discontinuous exercise was performed over 30 sec in each posture by flexing the hips to $45^0$ at a rate of 25 cycles $\cdot$ $min^{-1}$. Within each session, periods of 5 min rest in the sitting posture were interspersed between the performance of each postural or postural plus exercise condition to allow for proper equilibration before each stress was imposed.

Metabolic measurements were also performed during the first two sessions. Oxygen consumption ($\dot{V}O_2$) was chosen as the parameter to estimate the energy expenditure during the postural and postural plus exercise stress. Measurement of $\dot{V}O_2$ was performed during the third minute of each postural exposure. The last four sessions were designed to investigate the hemodynamic responses to postural and postural plus exercise stress. The number of hip flexions performed were 7, 8, and 10 for the inverted, supine, and standing postures, respectively. This investigation included measurement of heart rate and brachial arterial SBP, DBP, and MAP. The four sessions of postural stress enabled the investigator to determine whether or not an ordering effect occurred while progressing from one postural condition to successive conditions. The statistical analyses revealed no ordered effect occurred for any of the dependent measures.

The first objective of this study was to determine if there were any differences in oxygen consumption at rest, during exercise in the inverted posture, the supine, and the standing postures. The $\dot{V}O_2$ in the inverted posture at rest was found to be 1.7% greater than that for the standing posture and for the supine posture. These findings disagree with those observed by McMichael (1937) and Loeppky and Luft (1975) demonstrating $\dot{V}O_2$ decreased as man assumed the upright posture. Additionally, a strongly significant increase in $\dot{V}O_2$ during exercise in the head-down posture was observed and this finding was consistent with the investigation by Gazenko and associates (1980). Oxygen Consumption($\dot{V}O_2$) in the inverted posture was 7% and 36.5% greater hean in the supine and standing postures, respectively.

The second objective of this study was to determine if there were any differences in heart rate (HR) and blood pressure (SBP, DBP, MAP) responses of men at rest or during exercise in the inverted posture as compared to the supine and standing postures. The heart rate was measured immediately after 30 sec of exercise of each minute of postural exposure while BP was measured during the last 10 sec of each 3 min trial.

In the first minute of the exercise and non-exercise postural exposures, the highest heart rate was observed in the standing posture. No interaction was found between posture and mode (exercise vs non-exercise). The heart rate responses followed the same pattern, the values were just greater during exercise. The statistical analyses revealed that the heart rate in the standing posture was significantly greater than the heart rate in the supine posture. In the second minute, heart rate in standing posture remained significantly higher than in the supine posture. During the third minute, heart rate in the standing posture and heart rate in the inverted posture during rest and exercise were again greater than in the supine posture with no remarkable change from that of the second minute.

The heart rate response to passive inversion (non-exercise) appears to disagree with the results of previous investigations by Klatz and associates (1983, 1985) which demonstrated that heart rate during inversion was usually higher than in other positions when the baseline posture was sitting. Klatz and associates contended that emotional and psychologic factors could have contributed to the observed increases in heart rate which indicate a nervous system response. Katkov and associates (1979) found changes in ventricular systolic pressure consistent with increased shifting of the blood toward the head with $-20^{0}$ head-down tilt for 3 hours. These changes included decreased left ventricular pressures and increased heart rate. The sympathetic response associated with the emotional involvement of tilting appeared to counteract the anticipated decrease in heart rate associated with increased carotid pressure. This investigation is consistent with other investigators, such as Lemarr and associates (1983), reported reductions in heart rate when the individual was transferred from the supine to the head-down posture.

The heart rate response to exercise in various postures was similar to the heart rates in the non-exercise postural exposures (Figure 4). The results of this investigation coincided with those of Gazenko and associates (1980), who evaluated central circulation and metabolism of man during arm exercise in the head-down position. Seven individuals performed arm exercise in the $-30^0$ posture without exercise. The previously mentioned sympathetic response coupled with the increased metabolic requirement to perform inverted hip-flexion exercise may diminish the baroreceptor sensitivity, thus resulting in an increased heart rate.

Blood pressure responses to exercise and non-exercise postural exposures (upright, supine or inverted) were similar. No significant variation in SBP was observed between the supine, standing, or inverted posture. The inclusion of exercise significantly elevated SBP($F=45,65$;df1,10;$p<.05$). The Tukey procedure revealed that the mean SBP of 128.4 was significantly higher than the non-exercise SBP of 118.8 mmHg. However, the DBP and MAP analyses revealed significant differences due to posture. DBP in the standing posture was significantly greater than in the supine. The analysis of variance for the main effect of posture on MAP was found to be strongly significant ($p < .001$); specifically, MAP standing was greater than MAP in the inverted and supine postures.

The previous literature has been mixed with regard to the effects of inversion on blood pressure. Related to differences in BP may be the position of the arm during the postural trial and measurement of the blood pressure. LeMarr and associates (1983) allowed the arms to hang beside the head during inversion in their investigation of the cardiorespiratory responses to inversion; thus, BP was measured with the arm in this position. They observed significant increases in SBP and DBP with inversion; however, the baseline standing BP measurement was taken with the arm beside the torso. Klatz and associates (1983) also allowed the arms to hang beside the head during inversion until the time of BP measurement. At that point, the arm was abducted from the body. Significant increases in SBP and DBP were also observed.

In the investigation reported herein, the arms were maintained in the anatomical position by using nonconstricting rope loops around each wrist. Since the BP cuff was placed at or anatomically inferior to the heart level, any blood volume changes induced by the inversion procedure would also affect the results of the measurement. It is reasonable to assume that the height of a column of blood (brachial artery) will have a significant effect on the pressure being exerted upon it. Therefore, when the arms are hanging beside the head in the inverted posture, the height of the column of blood is much greater than the height of the column in the sitting, standing, or supine postures with the arm resting beside the torso.

This investigator has not found any previous investigations on the circulatory effects of $-90^{0}$ head-down tilt in which the arms were maintained in the same position throughout the testing. This investigation provides data which support those findings in earlier investigations wherein SBP had not significantly increased in the head-down posture or had initially increased and subsequently decreased within a 3 minute period (9,14,15,41).

Based on these results, it is concluded that $\dot{V}O_2$ during passive $-90^0$ head-down tilt is approximately 1.7% greater than in the standing and supine postures, respectively. During exercise, $VO_2$ is lowest in standing and higher in standing and highest in $-90^0$ inversion.

## Implications for Practitioners

This research has implications for the practitioners in that the hemodynamic responses to passive and active inversion do not necessarily indicate that it is an unsafe activity. However, this extends to only measurements of heart rate and brachial arterial blood pressure in 19-23 year old male recreational athletes.

## Recommendations for Future Research

The results of this investigation when viewed in context of the results reported by other researchers involving body inversion at rest and exercise (Chapter II) indicate a variety of important issues which remain unresolved. If a follow-up study is to be utilized to substantiate the findings reported herein, I offer two recommendations: a) examine the responses over a longer exercise period, and b) restrict involvement of ancillary muscle groups during hip-flexion exercise using mechanical constraints or educational session on the desired movement. The increased time may allow the hemodynamic parameters to "steady-state" to the demand of the work. It appeared that while some individuals predominantly depended upon strong contractions of the iliopsoas muscles to perform inverted hip-flexion activity (keeping the back straight), others utilized the rectus abdominus to a large extent and flexed the trunk. Teaching this movement to minimize the iliopsoas involvement may give a more accurate description the metabolic and hemodynamic requirements of this activity by standardizing this movement.

This study leaves many questions unresolved about the metabolic and hemodynamic responses to rest and exercise in the head-down tilt. There is still little known about the blood volume changes associated with head-down tilt. Further research in this area will enhance interpretation of the findings reported herein through description of the impact that autoregulation and other peripheral responses play on the function of the heart in various postures. Continued study of the complete head-down posture is also needed in the following areas:

1. Determination of brachial arterial blood pressure responses when the arm is maintained in various positions and the body is tilted from upright to the inverted postures. This may provide a means to predict the changes in blood pressure when an individual shifts from one posture to another.
2. Determination of carotid sinus pressure during exercise and non-exercise in the $-90^{0}$ head-down posture may provide more precise suggestions as to the effects on intra-cranial pressure. Carotid sinus pressure (measured invasively) would be a close representation of intra-cranial pressure.
3. Determination of cardiac output in the head-down posture with and without exercise may provide additional information concerning the response of the heart to the increased pressure associated with the rush of blood to the upper torso.

4. Determination of peak aortic blood flow acceleration, i.e., measurement of left ventricular performance might provide additional information on the changes and effect of preload volume in various postures.

References


1. American College of Sports Medicine. Guidelines for Graded Exercise Testing and Exercise Prescription, 1980.

2. American Heart Association. Measurement of Blood Pressure, 1980.

3. American Medical Association. The American Medical Association Guide to Backcare - Revised and Updated Edition, 1984.

4. Asmussen, E., E. H. Christensen, and M. Nielsen. The regulation of circulation in different postures. Surgery. 8:604-616, 1940.

5. Bellavere, F. and D. J. Ewing. Autonomic control of the immediate heart rate response to lying down. Clinical Science. 62, 57-64, 1982.

6. Bonde-Petersen, F., N. J. Christensen, O. Henriksen, B. Nidsen, C. Nielsen, P. Norsk, L. B. Powell, T. Sadimoto, G. Sjogaard, K. Kleagen, Y. Suauki. Aspects of cardiovascular adaptation to gravitational stress. The Physiologist. 23:5-7, 5-10, Dec., 1980.

7. Borst, C., W. Weiling, J. F. M. van Brederode, A. Hond, L. G. De Rijk, and A. J. Dunning. Mechanisms of initial heart rate response to postural change. Am. J. Physiol. 243 (Heart Circa Physiol. 12): H676-H681, 1982.

8. Carswell, H. Even for experienced lifters, overdoing it can pose a threat. Medical Tribune. 24:33, 1983.

9. Ellis, M. M. Pulse rate and blood pressure responses of men to passive postural changes. Amer; J. Med. Sci. 131:568-578,1921.

10. Fascenelli, F. W. and L. E. Lamb. Biomechanical monitoring during dynamic stress testing: V. Tilt table orthostatic tolerance test. Aerospace Med. 37:939-942, 1966.

11. Gazenko, O. G., V. I. Shumakov, L. I. Kakurin, V. E. Katkov, V. V. Chestukhin, V. M. Mikhailov, A. Z. Troshin, and V. N. Nesvestov. Central circulation and metabolism of the healthy man during postural exposures and arm exercise in the head-down position. Aviat Space Environ. Med. 51(2):113-120, 1980.

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

13. Goldman, R. M., R. S. Tarr, B. G. Pinchuk, R. E. Kappler, G. Slick, K. E. Nelson. More on gravity inversion. The Western J. of Med. 141(2):247, August, 1984.

14. Green, R. S., A. Iglaver, and J. McGuire. Alterations of radial or brachial intra-arterial blood pressure and of the electrocardiogram induced by tilting. J. Lab Clin Med. 33:951-960, 1948.

15. Henderson, Y. and H. N. Haggard. The circulation in man in the head-down position, and a method for measuring the venous return to the heart. J. Pharmacol Experi Therap. 11:189-201, 1918.

16. Henry, J. P. The Physiology of Negative Acceleration. Wright-Patterson Air Force Base Report (TR 5953). 1950.

17. Hill, L. On rest, sleep, and work and the concomittant changes in the circulation of the blood. Lancet. 1:282, 1898.

18. Jackson, A. S., and M. L. Pollock. Anthropoemetric estimation of body fat. In Golding, L. A., C. R. Myers, and W. E. Sinning, (eds.): The Y's Way to Physical Fitness. Rosemont:YMCA of the USA, 78-83, 1982.

19. Katkov, V. E. and V. V. Chestokhin. Blood pressure and oxygenation in different cardiovascular compartments of a normal man during postural exposures. Avait. Space Environ. Med. 51(11):1234-1242, 1980.

20. Katkov, V. E., V. V. Chestukhin, R. I. Lapteva, V. A. Yakovleva, V. M. Mikhailov, O. K. Zybin, and V. N. Vtkin. Central and cerebral hemodynamics of the healthy man during head-down tilting. Aviat. Space Environ. Med. 50(2):147-153, 1979.

21. Klatz, R. M., R. M. Goldman, B. G. Pinchuk, K. E. Nelson, R. S. Tarr. The effects of gravity inversion procedures on systemic blood pressure, intraocular pressure, and central retinal arterial pressure. J. Am. Osteopath Assoc. 82(7):853-857, 1983.

22. Klatz, R. M., R. M. Goldman, B. G. Pinchuk, R. S. Tarr. Effects of gravity inversion on hypertensive subjects. The Physician and Sports Medicine. 13(3):85-89, March, 1985.

23. Klein, K. E., H. Bruner, D. Jovey, H. M. Wegmann. Influence of stature and physical fitness on tilt-table and acceleration tolerance. Aerospace Med. 40:293-297.

24. Kunkle, E. C., R. R. Hernandez, W. T. Johnson, J. A. Baumann. Adaptive responses of cranial vessels in the head-down position. Transaction of the Am Neuro Assoc. 87:151-153, 162.

25. Lamb, L. E. and J. Roman. The head-down tilt and adaptability for aerospace flight. Aerospace Med. 32:473-486, 1961.

26. LeMarr, J. D., L. A. Golding and J. G. Adler. Intraocular pressure response to inversion. Amer. J. Opthal. and Physiol. Optics. 61(11):679-682, 1984.

27. LeMarr, J. D., L. A. Golding and K. D. Crehan. Cardiorespiratory responses to inversion. Phys Sports Med. 11:51-57, 1983.

28. Loeppky, J. A. and U. C. Luft. Fluctuations in oxygen stores and gas exchange with passive changes in posture. J. Appl. Physiol. 39:47-53, 1975.

29. Lynch, J., J. M. Long, S. A. Thomas, K. L. Malinow, A. H. Katcher. The effects of talking on the blood pressure of hypertensive and normotensive individuals. Psychosomatic Medicine. 43(1):pp. 25-33, 1981.

30. Martin, R. M. Gravity Guiding System. Gravity Guidance Inc., 1982.

31. Martin, R. M., II. DMT: Decompression Mobilization Therapy, Gravity Guidance, Duarte, CA., 1985.

32. McMichael, J. Quart. J. Exptl.Physiol. 27:55, 1937.

33. Metalon, S. V. and L. E. Farhi. Cardiopulmonary readjustments in passive tilt. JAP. 47:503-507, 1979.

34. Mengesha, Y. A. and G. H. Bell. Forearm and finger blood flow responses to passive body tilts. J. Appl. Physiol: Respirat. Environ. Exercise Physiol. 46(2):288-292, 1979.

35. Nixon, T. V., R. G. Murray, C. Bryant, T. L. Johnson, J. H. Mitchell, O. B. Holland, C. G. Sanchez, P. Vergne-Marine and C. G. Glomgvist. Early cardiovascular adaptation to simulated zero gravity. J. Appl. Physiol: Respirat. Environ. Exercise Physiol. 46(3):542-548, 1979.

36. Ramsey, M. Noninvasive automatic determination of mean arterial pressure. Med. Biol. Eng. Comput. 17:11-18, 1979.

37. Renfrew, R. A. (ed.), Inversion and blood pressure. The Physician and Sports Medicine. 12(2):15, 1984.

38. Sancetta, S. M. Acute hemodynamic effects of total head-down body-tilt and hexamethonium in normal and pulmonary emphysematous subjects. J. Lab. Clin. Med. 49:684-693, 1957.

39. Sheppard, R. J. (Ed), Cardiorespiratory responses to inversion. Sports Medicine. 1983.

40. Wald, H., M. Guernsey, and F. Scott. Some effects of alteration of posture on arterial pressure. Amer. Heart J. 14:319-330, 1937.

41. Wilkins, R. W., S. E. Bradey and C. K. Friedland. The acute circulatory effects of the head-down position (negative G) in normal man, with a note on some measures designed to relieve cranial congestion in this position. J. Clin. Investigation. 29:940-949, 1950.

Appendix A
Methodology

## Introduction

The purpose of this investigation was to measure the hemodynamic and metabolic responses to postural change with and without exercise. Oxygen consumption ($\dot{V}O_2$), heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) were the physiological parameters selected evaluated.

This appendix describes the methods and procedures employed in the investigation. Sections are included concerning the topics of subject screening and selection, informed consent information, preliminary testing and orientation, experimental conditions and design, and statistical analysis.

## Subject Screening and Selection

Thirteen male recreational athletes volunteered for inclusion in this study. Of these, eleven were selected. The age of these eleven subjects averaged 21.18 ± 1.33 yrs. Descriptive data are presented in Table 1. Preliminary screening and testing of the prospective subjects was performed to:

a. ensure that each subject was apparently healthy and possessed a fitness level adequate for performance of the exercise tasks and postural stress. This was accomplished by excluding any subject possessing symptoms of postural change intolerance (i.e., vertigo, headache, extreme sinus congestion, pain, etc.).

b. provide a homogenous sample in terms of habitual training, percent body fat, familiarity to inversion techniques, and tolerance to orthostatic stress.

c. minimize subject anxiety and learning effects which might contribute to extraneous variability in the dependent measures.

2. The criteria for selection of subjects are outlined below. Each subject:

a. was classified as a recreational athlete, i.e., non-team member, non-competitively trained athlete, etc.

b. had not recently begun a fitness or sports training program.

c. had a body fat content of less than 20%.

d. had no symptoms of exertional intolerance with exercise.

Initial data collection, including an interview for health and physical activity habits, a health history, as well as measurement of resting HR, SBP, DBP, and MAP provided the basis for subject selection.

## Human Subjects Review and Informed Consent

Permission to conduct this study was obtained from the Human Subjects Committee of the Health, Physical Education, and Recreation Department, and the Chairman of the Institutional Human Subjects Review Board of Virginia Polytechnic Institute and State University. Informed consent was secured from each subject prior to his participation in the study. (See Appendix C for forms.)

## Initial Testing and Orientation

Anthropometric measurements including height, weight, and skinfold for determination of percent body (skinfold calipers) were part of the initial testing for those qualifying at the screening visit to the laboratory (Table 4). Percent fat was assessed by the method of Jackson and Pollock (18).

Cardiovascular fitness was assessed using a graded submaximal exercise test using bicycle ergometry in which the electrocardiogram (ECG) and BP were repeatedly measured. The endpoint for this exercise test was approximately 85% of the age-adjusted predicted maximal heart rate. Termination for this test was determined by the criteria set forth by the American College of Sports Medicine (1).

Following initial testing, if there was no evidence of contraindications to further participation, the subjects were given an orientation to the experiment. Each performed a brief inversion of 1-2 min on the gravity oscillator (depicted in Figure 1) and became fully familiarized with the procedures of the study. Those experiencing severe sinus congestion, dizziness, or any other unusual distress were excluded from further participation.

## Experimental Conditions and Design

The subjects participated in six experimental sessions on a gravity oscillator. All sessions were performed in the Laboratory for Exercise, Sport and Work Physiology at Virginia Polytechnic Institute and State University. The ambient temperature was maintained between 22.5 - 26.5$^{O}$C. The subjects were asked to refrain from vigorous activity on the days of their sessions and to report to the laboratory at the same time of day for each of the sessions. Subjects proceeded through sessions 1-6 as listed in Table 2. Sessions 2-6 were order counter balanced for the group. Sessions were separated by at least 36 hours.

The duration of each postural trial was 3 min in each session. All metabolic and hemodynamic measurements were taken in the supine, standing, and inverted postures and hemodynamic measurements were taken in the seated posture during equilibration. Data was recorded on the test sheet (Table 3). In the sessions where exercise was coupled with postural stress, a metronome was used to pace trunk-flexion activity to $45^0$ (hip-flexion was measured by goniometry).

Table 3

## TEST SHEET

Name: ______________________ Age: __________

Ht: ______ Wt: ______ Skinfolds: Chest: ______

Ambient Temp: ______ Abdomen: ______

Wet Bulb: ______ Thigh: ______

pBar: ______ Percent Fat: ______

Trial No.: ______

| | | $\dot{V}_E$ | $F_EO_2$ | $F_ECO_2$ | HR | SBP | DPB | MAP | Measured $\dot{V}O_2$ |
|---|---|---|---|---|---|---|---|---|---|
| | EQ | | | | | | | | |
| | 1 | | | | | | | | |
| Supine | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| | EQ | | | | | | | | |
| | 1 | | | | | | | | |
| Standing | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| | 1 | | | | | | | | |
| Inverted | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| | 1 | | | | | | | | |
| Supine | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| | 1 | | | | | | | | |
| Standing | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| | 1 | | | | | | | | |
| Inverted | 2 | | | | | | | | |
| | 3 | | | | | | | | |

Table 4. Subject Characteristics .

| Subject | Age | Height (cm) | Weight (kg) | Body Fat (%) |
|---|---|---|---|---|
| 1 | 21 | 175.0 | 65.8 | 7.0 |
| 2 | 21 | 180.5 | 71.5 | 16.5 |
| 3 | 19 | 175.0 | 79.5 | 13.4 |
| 4 | 22 | 182.8 | 76.7 | 12.3 |
| 5 | 22 | 176.0 | 71.5 | 9.8 |
| 6 | 19 | 177.5 | 76.7 | 8.0 |
| 7 | 23 | 173.0 | 68.2 | 12.2 |
| 8 | 21 | 176.0 | 62.2 | 4.2 |
| 9 | 23 | 181.7 | 71.0 | 16.5 |
| 10 | 21 | 175.3 | 78.5 | 12.5 |
| 11 | 21 | 176.0 | 66.8 | 5.1 |
| - | 21.2 | 177.2 | 72.7 | 10.7 |
| ±SEM | ± .39 | ± .93 | ±1.7 | ±1.27 |

Symbols (x, ±SEM) are mean and standard error.

Discontinuous exercise was performed in each posture by flexing the hips to $45^0$ over 30 sec. Within each session, 5 min rest intervals in the sitting posture were interspersed between the performance of each postural or postural plus exercise condition, to allow for cardiovascular equilibration before each stress was imposed.

## Metabolic Investigation

The metabolic investigation was performed during the first two sessions. Oxygen consumption ($\dot{V}O_2$) was chosen as the parameter to estimate the energy expenditure during postural and postural plus exercise stress.

### Procedure for Measurement of Oxygen Consumption

There were two reasons for performing the metabolic measurements in trials that were separate from those in which the hemodynamic measurements were taken:

1. It was desired not to have to account for the weight and awkwardness of the mouthpiece, head harness, and hoses of the gas analysis system during the hemodynamic investigation.
2. It was also desired to adjust the workload of the two least demanding postural plus exercise trials (by increasing hip-flexion repetitions) to equate the most demanding stressor. This was done in order to "rule out" the metabolic response to varying work during the hemodynamic investigation.

The calculations were performed as follows:

The inverted hip-flexion activity required the greatest oxygen consumption which equalled 10.18 ml $\cdot$ $kg^{-1}$ $\cdot$ $min^{-1}$. The hip-flexion in the supine posture was the next most demanding metabolically with an $VO_2$

of 9.48 ml · $kg^{-1}$ · $min^{-1}$. Standing hip-flexion required only 6.47 ml · $kg^{-1}$ · $min^{-1}$. The supine hip-flexion activity was accepted as demanding 93% of the inverted posture [(9.48/10.18*100]. Therefore, the number of repetitions in the supine posture should have been increased by .07% or .5 repetitions. For practicality, the number of repetitions were increased by 1 repetition · $min^{-1}$. In the same manner, the standing hip-flexion activity was found to be [(6.47/10.18)*100] or 64% of the inverted posture. Therefore, 3 additional repetitions in the standing posture were required to equate the $\dot{V}O_2$ of the inverted posture. Therefore, to equate the amount of work performed, the number of hip flexions performed were 7, 8, 10 for the inverted, supine, and standing postures respectively. Each subject was advised of the number of repetitions to be performed and the repetitions were called out in cadence by the investigator.

Oxygen uptake ($\dot{V}O_2$) was measured in the following manner:

1. Each subject was properly fitted into the inversion boots and instructed to sit upon the gravity oscillator as illustrated in Figure 1a. The investigator then adjusted the oscillator to accommodate for the subject's height and weight to assure proper balance and weight distribution on the inversion apparatus.
2. After carefully explaining the test to the subject, the investigator fitted the individual with an appropriate mouthpiece and head harness. A nose clip was placed on the individual's nose and the mouthpiece was placed within the mouth.
3. The respiratory hose attached to the mouthpiece was connected to a Hewlett-Packard Pneumotach (Model A-7303A) for the determination of the min ventilation volume (expired air, $V_E$).
4. The expired air was collected in a 4 liter plexigas mixing chamber.

These gases within the chamber were continually monitored for percent oxygen and carbon dioxide during each min of the experimental sessions. The respiratory hose leading from the mouthpiece to the gas trap was kept to a minimum and was always less than 1 meter in length.

5. The oxygen content of the dry expired air was determined using a Rapid Response Applied Electrochemistry Oxygen Analyzer (Model CDE-3AAA) after first passing the gas through a dessicating column. The analyzers were calibrated prior to and during each test with standard gases verified through Haldane analysis.
6. The investigator assisted each subject into the posture to be examined. In the passive postural trials, the subject was asked to breathe at the most comfortable rate. During the exercise trials, it was requested that the subjects exhale during the contraction phase of each hip- flexion cycle to prevent Valsalva effects. The hip-flexion cadence during the exercise trial was maintained by using a metronome calibrated to 30 clicks $\cdot$ $min^{-1}$. Exercise was performed during the first 30 sec of each min for 3 consecutive minute. The last 30 seconds of each minute, the subject rested during measurement of the parameters.
7. The oxygen and carbon dioxide content of expired gas and the volume of air ventilated was recorded the third minute of each postural exposure. (Tables 5-6)
8. Oxygen uptake was recorded during the last minute of the postural exposure.

Hemodynamic Investigation

The last four experimental sessions served to provide the basis for assessment of the hemodynamic responses. This investigation included measurement of HR and brachial arterial BP which required the use of an electrocardiograph and automated blood pressure cuff. A description of measurement techniques and protocol for HR and BP are outlined below.

Procedure for Measurement of Heart Rate

Heart rate was measured using a Hewlett-Packard ECG recorder with a CL5 lead. The rate was calculated by measurement of R to R wave intervals.

1. Once the individual was properly seated on the oscillator, the investigator prepped the skin and attached diaphoretic silver chloride electrodes to each shoulder in the space between the anterior deltoid and the clavicle and a third electrode to the anterior mid-axillary region and the fifth intercostal space. The left arm electrode served as the electrical ground.
2. An electrocardiographic tracing was recorded at the beginning of each session. The individual was then allowed to rest in the sitting position on the oscillator for 15 min before the baseline (time zero) measurement was recorded.
3. Subsequent recordings were made during the last 5 sec of exercise (25-30 sec) for every min of each 3 min trial (supine, standing, and inverted) as well as for the last 5 sec of each min (55-60 sec). Tables 7-10.
4. The ECG tracings were made after 4:50 min of rest in the equilibration periods to ensure that heart rates had returned to baseline level.
5. The electrocardiograph was calibrated in accordance with the manufacturer's directions.

Procedure for Measurement of Systemic Arterial Blood Pressure

Systemic arterial blood pressure (SBP, DBP, and MAP) was measured using a DINAMAP™ Adult/Pediatric Vital Signs Monitor (Model 845XT) from Critikon, Inc. (see Appendix D). This monitor automatically measures HR, SBP, DBP, and MAP noninvasively using the oscillometric technique, as previously described (36). The Dinamap 845XT has been shown to have a high correlation between its measurements and intra-arterial measurements of blood pressure (29, 36). The calibration and operation of the DINAMAP™ was performed in accordance with the standards described in detail in the abbreviated operating manual which is presented as Appendix D. Preparation and measurement protocol was performed in the following manner:

1. Each subject was seated on the gravity oscillator as pictured in Figure 1a.
2. The DINAMAP pressure cuff was positioned over the left arm in accordance with the standards of the American Heart Association (2) and the DINAMAP 845XT operating manual (Appendix D). The brachial artery was located, marked, and the cuff bladder centered over the artery.
3. To ensure that the arm would be kept in the same position throughout the testing, a non-constricting rope loop was placed around each hand and the rope secured to the oscillator. The subject was instructed not to tense his arm muscles in order to maintain this position, but rather to let them hang limp from the ropes (Figure 1).
4. The BP monitor was manually activated for spontaneous measurement on command. The cuff would inflate to approximately 170 mmHg. If the artery was not occluded at that point, it would inflate again until a significant amount of pressure was applied to

occlude the artery. If cuff inflation was greater than 275 mmHg (nominal), the overpressure switch would automatically deflate the cuff. After the artery was occluded, the cuff would deflate in average increments of approximately 8 mmHg. Rate of cuff deflation was dependent upon initial inflation pressure and the HR. Each measurement required approximately 40 sec.

5. The cuff was inflated 4:20 min after the equilibration period and 2:20 min of each postural event and measurements were recorded on the test sheet (Table 3). The SBP, DBP, and MAP data are presented in Tables 13-27.

## Statistical Analysis of Dependent Measures

In order to analyze the data, it was first necessary to determine if any part of the experimental procedure altered the results of this investigation. Two potential problems existed in the design. First, it was necessary that the hemodynamic parameters were allowed enough time to equilibrate in the sitting posture before any measurement of data under the forementioned conditions would be considered valid. Therefore, each subject was seated upon the oscillator as depicted in Figure 1a for 15 min prior to the first postural exposure. Subsequent equilibration periods of 5-8 min occurred after the sec and third postural exposures. Measurement of the hemodynamic parameters at the end of each equilibration period was performed to ensure the body had readjusted to the sitting posture. The GLM model statement for equilibration measures used was: model HR SBP DBP MAP = sequence trial sequence * trial. This enabled the investigator to estimate whether or not there was a statistically significant difference in equilibration measures for each parameter examined after each postural exposure. The repeated measures ANOVA resulted in F values for HR, SBP, DBP, and MAP of 6.50, 3.38, 4.59, and 2.57, respectively, none of which revealed any statistically significant difference ($p > .05$) between the equilibration periods in any of the parameters examined. The actual levels of significance for each parameter were .57, .52, .39, and .71, respectively.

Second, since all subjects proceeded through sessions one through six in the same order, it was suspected that an ordering effect might have occurred. To analyze the data to make sure this did not occur, the investigators totaled the third min responses for each of the hemodynamic parameters according to the order in which each session occurred (Table 2). The GLM model statement used was: model HR SBP DBP MAP = MODE ORDER MODE*ORDER. This particular model examined the effects of mode (exercise versus nonexercise), ordering (the progression of various tilts), and the interaction of mode and order. The repeated measures ANOVA test resulted in F-values for HR, SBP, DBP, and MAP equal to 3.67, 4.85, 1.96 and 1.50 respectively of which none were significant below the .05 level. The actual level of significance for each parameter was .68, .34, .58, and .86 for HR, SBP, DBP, AND MAP respectively (Tables 24-50).

After the analysis on the equilibration and ordering effects was completed, the analysis on the effects of posture was performed. The following is a description of the statistical analysis of each of the parameters as related to exercise and non-exercise in the supine, standing, and inverted postures..

Oxygen Consumption

Oxygen Consumption ($\dot{V}O_2$) was analyzed using the repeated measures ANOVA and the .05 Tukey's Studentized Range (HSD) Test to determine significant differences between exercise and nonexercise positioning. A significan difference was observed between rest and exercise in the various positions(F=20.93;df=1,10p .05). No significant effect relative to body position(F=3.60;df = 2,10; p .05) was observed. Examination of rest versus exercise in Figure 3 illustrates the significant increase in $\dot{V}O_2$ during exercise.

Heart Rate

To analyze the third minute heart rate responses to posture, mode, and the interaction of posture and mode, a repeated measures analysis of variance procedure was employed. Heart rate response to rest and exercise during postural exposure are graphically illustrated in Figure 4. The third min HR response to NE postural exposure was found to be significantly different(F = 7.79;df = 2,20; p<.05). The Tukey procedure revealed that the NE standing posture ($\bar{x}$ = 89 beats $\cdot$ $min^{-1}$) than the NE supine postural exposure ($\bar{x}$ = 61 beats $\cdot$ $min^{-1}$)and inverted postural exposure(x = 61 bts $\cdot$ $min^{-1}$).

The repeated measures analysis of varience was also employed to examine heart rates of the third min of E postural stress. The third min HR responses revealed the standing E heart rate was significantly faster than the supine position(Tukey procedure, p<.05) (F = 7.79;df = 2,20;p .05) in regard to posture during the 45° hip-flexion activity. The test resulted in an F-value of 7.79.

Blood Pressure

The statistical analysis of the arterial systolic (SBP), diastolic (DBP), and mean arterial pressure (MAP) was performed using the GLM analysis of variance procedure to determine significant differences in BP due to postural changes. The Tukey Studentized (HSD) Range Test was employed to discriminate significant postural changes. The GLM model statement used was: Model SBP DBP MAP = SUBJECT POSITION MODE POSITION * MODE. The test resulted in an F-value for SBP equal to 1.73 for position which was not significant below the 0.05 level (actual level of significance was p = .1978). This test further indicated that differences in mode (NE versus $45^0$ hip-flexion activity) were significantly different (p = .0001). The mean E and NE SBP was 128.42 and 118.83 mmHg, respectively. However, the interaction between posture and mode (NE and E) did not significantly affect SBP (the actual level of significance was p .4853).

The test revealed an F-value for the analysis of DBP as it relates to position equal to 5.96 which was significant at the 0.05 level. The actual level of significance was found to be $p < .0001$. A significant difference was also indicated between E and NE with an F-test equal to 8.02 (the actual level of significance was .0055. The mean values for E and NE were 74.96 and 70.88 mmHg respectively. The interaction between posture and mode (static tilting vs $45^0$ hip-flexion exercise) was not significant in regard to DBP at the 0.05 level (the actual level of significance was p= .2974).

The Tukey analysis for DBP resulted in Q-values which were significant at the 0.05 level (Q= 3.358), for each posture. This indicated that the DBP in the standing posture (at rest and exercise) was significantly higher than in the inverted and supine postures. Furthermore, the DBP in the inverted posture was significantly elevated above that found in the supine posture.

Mean arterial pressure was analyzed and resulted in an F-value equal to 13.21. This indicated a significance difference in MAP at the 0.05 level of confidence for position (actual level of confidence was p= .0001). A significant difference between NE and E during each postural exposure was indicated with an F-value equal to 17.36 (the actual level of significance was p= .0001). However, no significant interaction between posture and mode (NE vs E) was found. The F-value was .38 and actual level of significance p= .6848.

The Tukey procedure for MAP revealed a significant Q value equal to 3.358. This revealed that the MAP was found to be significantly higher in the standing posture than in the inverted and supine postures. Furthermore, the test indicated the MAP in the inverted posture was greater, although nonsignificantly, than in the supine posture.

# Appendix B
# DATA TABLES

Table 5. Third minute oxygen consumption ($VO_2$) ($ml \cdot kg^{-1} \cdot min^{-1}$) response in subjects exposed to supine, standing and inverted postures at rest and during 45° hip-flexion activity.

| | SUN | STN | IN | SUE | STE | IE |
|---|---|---|---|---|---|---|
| $\bar{X}$ | 4.3 | 4.3 | 4.6 | 9.5 | 6.5 | 10.1 |
| SE | ±.2 | ±.2 | ±.4 | ±.5 | ±.3 | ±.8 |

$\bar{x}$ = Mean
SEM = Standard rror of the Mean
SUN = Supine Non-Exercise
STN = Standing Non-exercise
IN = Inverted Non-exercise
SUE = Supine Exercise
STE = Standing Exercise
IE = Inverted Exercise

Table 6. Oxygen Consumption ($\dot{V}O_2$) (ml · $kg^{-1}$ · $min^{-1}$) for subjects exposed to supine, standing, and inverted postures, under passive conditions. - Session I

| Subject | Time(min) in SUN 1 | 2 | 3 | Time(min) in STN 1 | 2 | 3 | Time(min) in IN 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.94 | 4.46 | 4.39 | 4.62 | 4.21 | 4.61 | 5.52 | 5.00 | 4.20 |
| 2 | 5.69 | 9.24 | 4.62 | 5.46 | 4.24 | 5.62 | - | 6.16 | 6.12 |
| 3 | 3.86 | 2.90 | 3.30 | 4.36 | 3.28 | 3.66 | 4.71 | 4.56 | 4.27 |
| 4 | 5.18 | 5.00 | 5.02 | 4.88 | 5.28 | 5.47 | 6.39 | 7.18 | 6.38 |
| 5 | 4.64 | 3.38 | 3.33 | 3.55 | 3.09 | 3.51 | 3.71 | 3.85 | 3.86 |
| 6 | 5.88 | 4.66 | 3.74 | 4.55 | 4.20 | 4.13 | 7.60 | 5.95 | 5.46 |
| 7 | 5.77 | 4.10 | 3.85 | 4.40 | 3.26 | 4.20 | 5.15 | 5.52 | 4.67 |
| 8 | 4.64 | 3.80 | 4.14 | 5.15 | 4.33 | 3.98 | 4.37 | 4.48 | 4.56 |
| 9 | 7.56 | 5.77 | 4.91 | 4.81 | 4.43 | 4.36 | 6.90 | 5.29 | 2.26 |
| 10 | 3.62 | 4.39 | 4.11 | 3.18 | 4.10 | 4.03 | 4.66 | 4.26 | 3.37 |
| 11 | 5.12 | 3.60 | 5.65 | 3.38 | 3.34 | 3.02 | 5.97 | 4.98 | 4.01 |
| 12 | 6.94 | 5.65 | 4.27 | 5.70 | 4.44 | 4.82 | 8.36 | 6.63 | 5.88 |
| $\bar{x}$ | 5.4 | 4.8 | 4.3 | 4.5 | 4.0 | 4.2 | 5.7 | 5.3 | 4.5 |
| SEM | ± .3 | ± .5 | ± .2 | ± .2 | ± .2 | ± .2 | ± .4 | ± .3 | ± .4 |

$\bar{x}$ = Mean

SEM = Standard Error

SUN = Supine Non-exercise

STN = Standing Non-exercise

IN = Inverted Non-exercise

Table 7. Oxygen Consumption ($\dot{V}O_2$) (ml $kg^{-1}$ $min^{-1}$) for subjects exposed to supine, standing and inverted postures under conditions of trunk flexion exercise. - Session II

| Subject | Time(min) in SUE | | | Time(min) in STE | | | Time(min) in IE | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1 | 8.60 | 8.98 | 9.52 | 6.28 | 6.08 | 5.82 | 6.84 | 7.25 | 7.03 |
| 2 | 8.49 | 7.87 | 9.50 | 7.10 | 6.33 | 5.74 | 9.37 | 11.73 | 13.21 |
| 3 | 6.50 | 7.46 | 8.44 | 5.05 | 4.72 | 5.87 | 7.62 | 9.99 | 13.95 |
| 4 | 7.18 | 9.08 | 11.34 | 6.77 | 6.92 | 7.46 | 8.69 | 10.06 | 13.70 |
| 5 | 8.31 | 9.14 | 11.08 | 5.21 | 4.97 | 4.76 | 8.00 | 8.41 | 8.48 |
| 6 | 7.58 | 7.83 | 8.30 | 5.48 | 7.71 | 7.33 | 6.28 | 7.20 | 6.11 |
| 7 | 7.03 | 7.90 | 9.17 | 6.10 | 6.40 | 6.92 | 6.55 | 7.84 | 6.94 |
| 8 | 7.32 | 8.17 | 10.34 | 7.07 | 6.75 | 7.10 | 6.84 | 7.78 | 10.79 |
| 9 | 11.17 | 11.59 | 12.40 | 6.16 | 6.23 | 6.05 | 9.04 | 10.17 | 11.45 |
| 10 | 6.64 | 6.69 | 6.70 | 5.02 | .19 | 6.36 | 6.48 | 7.21 | 9.27 |
| 11 | 5.77 | 5.57 | 7.40 | 5.97 | 7.35 | 6.22 | 7.89 | 5.74 | 9.45 |
| 12 | 10.14 | 8.32 | 9.61 | 8.25 | 8.02 | 7.97 | 11.37 | 10.98 | 11.81 |
| $\bar{x}$ | 7.9 | 8.2 | 9.5 | 6.2 | 6.4 | 6.5 | 7.9 | 8.7 | 10.2 |
| SEM | ± .5 | ± .4 | ± .5 | ± .3 | ± .3 | ± .3 | ± .4 | ± .5 | ± .8 |

$\bar{x}$ = Mean

SEM = Standard Error

SUE = Supine Exercise

STE = Standing Exercise

IE = Inverted Exercise

Table 8. Third minute heart rate (bt · $min^{-1}$) response of subjects exposed to supine, standing and inverted postures at rest and during $45^{o}$ hip-flexion activity.

| | SUN | STN | IN | SUE | STE | IE |
|---|---|---|---|---|---|---|
| x | 61.2 | 89.1 | 61.4 | 75.5 | 88.5 | 84.5 |
| SEM | ±9.9 | ±12.7 | ±4.9 | ±3.4 | ±4.2 | ±3.6 |

$\bar{x}$ = Mean

SEM = Standard Error

SUN = Supine Non-Exercise

STE = Standing Non-Exercise

IN = Inverted Non-Exercise

SUE = Supine Exercise

STE = Standing Exercise

IE = Inverted Non-Exercise

Table 9. Heart Rate (bt $min^{-1}$) for subjects exposed to supine, standing, and inverted postures under passive conditions. Session III

| Subject | EQ | Time(sec) in SUN | | | EQ | Time(sec) in STN | | | EQ | Time(sec) in IN | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 60 | 120 | 180 | | 60 | 120 | 180 | | 60 | 120 | 180 |
| 1 | 78 | 77 | 48 | 50 | 83 | 100 | 105 | 97 | 79 | 45 | 48 | 47 |
| 2 | 83 | 59 | 71 | 65 | 87 | 100 | 103 | 103 | 88 | 81 | 79 | 79 |
| 3 | 78 | 79 | 77 | 65 | 77 | 91 | 83 | 91 | 69 | 57 | 71 | 68 |
| 4 | 54 | 70 | 71 | 68 | 65 | 82 | 91 | 86 | 67 | 69 | 68 | 59 |
| 5 | 83 | 64 | 71 | 69 | 88 | 103 | 97 | 102 | 86 | 67 | 63 | 60 |
| 6 | 100 | 58 | 71 | 71 | 88 | 100 | 97 | 100 | 91 | 57 | 68 | 55 |
| 7 | 71 | 68 | 54 | 60 | 70 | 83 | 78 | 79 | 71 | 75 | 73 | 65 |
| 8 | 94 | 67 | 71 | 63 | 92 | 120 | 120 | 115 | 88 | 63 | 67 | 64 |
| 9 | 91 | 65 | 65 | 83 | 86 | 71 | 71 | 83 | 81 | 68 | 65 | 71 |
| 10 | 77 | 64 | 65 | 57 | 67 | 88 | 81 | 86 | 68 | 58 | 57 | 60 |
| 11 | 73 | 66 | 59 | 57 | 79 | 83 | 98 | 94 | 81 | 51 | 63 | 63 |
| $\bar{x}$ | 80.2 | 67.0 | 66.0 | 64.4 | 80.2 | 92.8 | 92.8 | 94.2 | 79.0 | 62.9 | 65.6 | 62.8 |
| SEM | ± 3.76 | ± 1.96 | ± 2.64 | ± 2.63 | ± 2.71 | ± 4.10 | ± 4.22 | ± 3.18 | ± 2.68 | ± 3.17 | ± 2.48 | ± 2.59 |

$\bar{x}$ = Mean

SEM = Standard Error

EQ = Equilibration

SUN = Supine Non-exercise

STN = Standing Non-exercise

IN = Inverted Non-exercise

Table 10. Heart Rate (bt · $min^{-1}$) for subjects exposed to supine, inverted, and standing postures under passive conditions. Session IV

| Subject | EQ | Time(sec) in SUN | | | EQ | Time(sec) in IN | | | EQ | Time(sec) in STN | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 60 | 120 | 180 | | 60 | 120 | 180 | | 60 | 120 | 180 |
| 1 | 58 | 41 | 41 | 40 | 75 | 41 | 41 | 41 | 44 | 68 | 68 | 77 |
| 2 | 94 | 70 | 73 | 54 | 81 | 68 | 81 | 73 | 88 | 115 | 94 | 111 |
| 3 | 91 | 61 | 52 | 71 | 81 | 60 | 60 | 75 | 83 | 100 | 90 | 83 |
| 4 | 60 | 59 | 60 | 56 | 60 | 56 | 63 | 60 | 57 | 70 | 67 | 70 |
| 5 | 77 | 71 | 68 | 68 | 77 | 77 | 83 | 54 | 71 | 88 | 83 | 83 |
| 6 | 71 | 58 | 58 | 56 | 68 | 60 | 56 | 56 | 79 | 97 | 97 | 94 |
| 7 | 48 | 53 | 50 | 48 | 65 | 61 | 60 | 52 | 53 | 51 | 48 | 61 |
| 8 | 107 | 60 | 51 | 56 | 94 | 65 | 62 | 67 | 83 | 97 | 86 | 97 |
| 9 | 79 | 79 | 61 | 75 | 83 | 68 | 63 | 70 | 83 | 86 | 75 | 94 |
| 10 | 79 | 70 | 67 | 65 | 75 | 75 | 70 | 68 | 79 | 94 | 97 | 94 |
| 11 | 49 | 45 | 45 | 45 | 54 | 47 | 44 | 47 | 54 | 64 | 77 | 68 |
| $\bar{x}$ | 74 | 61 | 57 | 58 | 74 | 63 | 62 | 61 | 70 | 85 | 80 | 85 |
| SEM | ± 5.72 | ± 3.46 | ± 3.03 | ± 3.34 | ± 3.44 | ± 3.28 | ± 3.90 | ± 3.37 | ± 4.66 | ± 5.73 | ± 4.68 | ± 4.50 |

$\bar{x}$ = Mean

SEM = Standard Error

EQ = Equilibration

SUN = Supine Non-exercise

STN = Standing Non-exercise

IN = Inverted Non-exercise

Table 12 Heart Rate (bt min$^{-1}$) for subjects exposed to supine, inverted and standing postures under conditions of trunk flexion exercise - Session V

| Subject | Time(sec) in SWE Posture EQ | 30* | 60 | 90 | 120 | 150* | 180 |
|---|---|---|---|---|---|---|---|
| 1 | 70 | 75 | 51 | 66 | 59 | 83 | 49 |
| 2 | 83 | 94 | 75 | 103 | 87 | 107 | 92 |
| 3 | 68 | 94 | 68 | 100 | 79 | 91 | 77 |
| 4 | 60 | 94 | 83 | 94 | 73 | 73 | 63 |
| 5 | 63 | - | 63 | 88 | 75 | 83 | 61 |
| 6 | 100 | 88 | 76 | 88 | 81 | 100 | 83 |
| 7 | 63 | 77 | 69 | 83 | 64 | 81 | 63 |
| 8 | 91 | 103 | 83 | 100 | 81 | 111 | 88 |
| 9 | 97 | 107 | 107 | 111 | 100 | 100 | 87 |
| 10 | 71 | 79 | 77 | 75 | 75 | 81 | 71 |
| 11 | 77 | 86 | 50 | 97 | 71 | 83 | 56 |
| $\bar{x}$ | 77 | 89 | 73 | 91 | 77 | 90 | 72 |
| SEM | ± 4.27 | ± 3.17 | ± 4.80 | ± 4.00 | ± 3.32 | ± 3.73 | ± 4.36 |

| Subject | Time(sec) in STE Posture EQ | 30* | 60 | 90* | 120 | 150* | 180 |
|---|---|---|---|---|---|---|---|
| 1 | 52 | 70 | 79 | 68 | 65 | 71 | 57 |
| 2 | 87 | 97 | 102 | 91 | 103 | 98 | 84 |
| 3 | 81 | 88 | 83 | 86 | 79 | 88 | 83 |
| 4 | 63 | 65 | 65 | 66 | 67 | 69 | 70 |
| 5 | 71 | 95 | 88 | 71 | 83 | 88 | 94 |
| 6 | 83 | 94 | 100 | 79 | 100 | 86 | 68 |
| 7 | 53 | 68 | 57 | 68 | 55 | 58 | 77 |
| 8 | 86 | 100 | 100 | 97 | 100 | 94 | 76 |
| 9 | 93 | 111 | 97 | 107 | 100 | 107 | 81 |
| 10 | 73 | 86 | 88 | 88 | 91 | 89 | 75 |
| 11 | 75 | 91 | 100 | 77 | 103 | 79 | 61 |
| $\bar{x}$ | 74 | 88 | 87 | 82 | 86 | 84 | 75 |
| SEM | ± 4.11 | ± 4.37 | ± 4.57 | ± 4.03 | ± 5.23 | ± 4.24 | ± 3.22 |

| Subject | Time(sec) in STE Posture EQ | 30* | 60 | 90* | 120 | 150* | 180 |
|---|---|---|---|---|---|---|---|
| 1 | 78 | 103 | 92 | 71 | 92 | 50 | 88 |
| 2 | 77 | 100 | 79 | 92 | 100 | 88 | 103 |
| 3 | 79 | 79 | 88 | 83 | 91 | 81 | 91 |
| 4 | 73 | 68 | 91 | 81 | 87 | 77 | 83 |
| 5 | 71 | 91 | 94 | 77 | 97 | 71 | 88 |
| 6 | 91 | 100 | 103 | 91 | 103 | 91 | 103 |
| 7 | 56 | 79 | 75 | 67 | 58 | 68 | 65 |
| 8 | 96 | 103 | 113 | 103 | 122 | 111 | 120 |
| 9 | 97 | 102 | 88 | 94 | 94 | 94 | 97 |
| 10 | 71 | 88 | 88 | 76 | 81 | 75 | 86 |
| 11 | 75 | 81 | 94 | 77 | 94 | 79 | 94 |
| $\bar{x}$ | 78 | 90 | 91 | 83 | 93 | 80 | 93 |
| SEM | ± 3.61 | ± 3.08 | ± 3.37 | ± 3.31 | ± 4.69 | ± 4.77 | ± 4.19 |

$\bar{x}$ = Mean

SE = Standard Error

EQ = Equilibration

SWE = Supine Exercise

STE = Standing Exercise

IE = Inverted Exercise

* = Post Exercise Measurement

Table 11. Heart Rate (bt · $min^{-1}$) for subjects exposed to supine, inverted and standing postures under conditions of trunk flexion exercise - Session VI

| Subject | Time(sec) in SUE Posture EQ | 30* | 60 | 90* | 120 | 150* | 180 |
|---|---|---|---|---|---|---|---|
| 1 | 73 | 102 | 73 | 97 | 75 | 86 | 91 |
| 2 | 77 | 100 | 72 | 103 | 91 | 103 | 83 |
| 3 | 77 | 88 | 73 | 88 | 86 | 94 | 83 |
| 4 | 88 | 87 | 68 | 88 | 68 | 92 | 75 |
| 5 | 83 | 86 | 94 | 103 | 86 | 100 | 68 |
| 6 | 83 | 91 | 81 | 94 | 86 | 97 | 88 |
| 7 | 70 | 81 | 71 | 96 | 75 | 82 | 75 |
| 8 | 86 | 90 | 79 | 107 | 68 | 102 | 71 |
| 9 | 94 | 83 | 81 | 107 | 88 | 94 | 79 |
| 10 | 67 | 86 | 75 | 82 | 79 | 67 | 88 |
| 11 | 77 | 88 | 70 | 79 | 56 | 79 | 68 |
| $\bar{x}$ | 80 | 89 | 76 | 94 | 78 | 90 | 79 |
| SEm | ± 2.44 | ± 1.96 | ± 2.23 | ± 2.93 | ± 3.25 | ± 3.41 | ± 2.48 |

| Subject | Time(sec) in IE Posture EQ | 30* | 60 | 90* | 120 | 150* | 180 |
|---|---|---|---|---|---|---|---|
| 1 | 83 | 91 | 51 | 81 | 61 | 90 | 57 |
| 2 | 86 | 97 | 81 | 106 | 87 | 103 | 84 |
| 3 | 81 | 94 | 97 | 94 | 81 | 91 | 83 |
| 4 | 68 | 88 | 83 | 103 | 66 | 103 | 70 |
| 5 | 107 | 103 | 88 | 107 | 94 | 100 | 94 |
| 6 | 91 | 88 | 60 | 83 | 79 | 94 | 68 |
| 7 | 58 | 86 | 77 | 86 | 71 | 81 | 77 |
| 8 | 88 | 115 | 79 | 111 | 79 | 107 | 76 |
| 9 | 75 | 86 | 83 | 94 | 94 | 97 | 81 |
| 10 | 70 | 83 | 70 | 83 | 78 | 86 | 75 |
| 11 | 83 | 71 | 58 | 81 | 61 | 86 | 61 |
| $\bar{x}$ | 81 | 91 | 75 | 93 | 77 | 94 | 75 |
| SEm | ± 3.93 | ± 3.43 | ± 4.21 | ± 3.53 | ± 2.52 | ± 3.22 | ± 3.22 |

| Subject | Time(sec) in STE Posture EQ | 30* | 60 | 90* | 120 | 150* | 180 |
|---|---|---|---|---|---|---|---|
| 1 | 78 | 103 | 92 | 71 | 92 | 50 | 88 |
| 2 | 77 | 100 | 73 | 92 | 100 | 88 | 103 |
| 3 | 79 | 79 | 88 | 83 | 91 | 81 | 91 |
| 4 | 73 | 68 | 91 | 81 | 87 | 77 | 83 |
| 5 | 71 | 91 | 94 | 77 | 97 | 71 | 88 |
| 6 | 91 | 100 | 103 | 91 | 103 | 91 | 103 |
| 7 | 56 | 79 | 75 | 67 | 58 | 68 | 65 |
| 8 | 95 | 103 | 113 | 103 | 122 | 111 | 120 |
| 9 | 97 | 102 | 88 | 94 | 94 | 94 | 97 |
| 10 | 71 | 88 | 88 | 75 | 81 | 75 | 86 |
| 11 | 75 | 81 | 94 | 77 | 94 | 79 | 94 |
| $\bar{x}$ | 78 | 90 | 91 | 83 | 93 | 80 | 93 |
| SEm | ± 3.61 | ± 3.68 | ± 3.37 | ± 3.31 | ± 4.69 | ± 4.77 | ± 4.19 |

$\bar{x}$ = Mean

SE = Standard Error

EQ = Equilibration

SUE = Supine Exercise

STE = Standing Exercise

IE = Inverted Exercise

* = Post Exercise Measurement

Table 13. Third minute systolic blood pressure (mmHg) responses in subjects exposed to supine, standing and inverted postures at rest and during 45° hip-flexion activity.

| | SUN | STN | IN | SUE | STE | IE |
|---|---|---|---|---|---|---|
| $\underline{x}$ | 117.5 | 117 | 127.5 | 129 | 127.5 | 129 |
| SE | ±3.1 | ±3.2 | ±3.0 | ±8.0 | ±2.9 | ±2.7 |

x = Mean
SEM = Standard Error
SUN = Supine Non-Exercise
STE = Standing Non-Exercise
IN = Inverted Non-Exercise
SUE = Supine Exercise
STE = Standing Exercise
IE = Inverted Non-Exercise

Table 14. Systolic Blood Pressure (mmHg) for subjects exposed to supine, standing, and inverted postures under passive conditions. - Session III

| Subject | EQ | SUN 3 | EQ | STN 3 | EQ | IN 3 |
|---|---|---|---|---|---|---|
| 1 | 111 | 106 | 104 | 107 | 106 | 109 |
| 2 | 120 | 134 | 135 | 135 | 144 | 127 |
| 3 | 114 | 113 | 118 | 99 | 102 | 115 |
| 4 | 133 | 121 | 123 | 108 | 120 | 128 |
| 5 | 112 | 108 | 121 | 116 | 127 | 126 |
| 6 | 118 | 118 | 116 | 119 | - | 119 |
| 7 | 103 | 113 | 106 | 101 | 108 | 111 |
| 8 | 118 | 120 | 130 | 123 | - | 121 |
| 9 | 128 | 136 | 138 | 139 | 112 | 137 |
| 10 | 124 | 127 | 117 | 120 | 124 | 131 |
| 11 | 118 | 119 | 117 | 120 | 118 | 117 |
| $\bar{x}$ | 118 | 120 | 120 | 117 | 106 | 133 |
| SEM | $\pm$2.5 | $\pm$2.9 | $\pm$3.2 | $\pm$3.9 | $\pm$3.8 | $\pm$2.6 |

$\bar{x}$ = Mean

SEM = Standard Error

EQ = Equilibration

SUN = Supine Non-exercise

STN = Standing Non-exercise

IN = Inverted Non-exercise

Table 15. Systolic Blood Pressure (mmHg) for subjects exposed to supine, inverted, and standing postures under passive conditions. - Session IV

| Subject | EQ | SUN 3 | EQ | IN 3 | EQ | STN 3 |
|---|---|---|---|---|---|---|
| 1 | 103 | 95 | 107 | 106 | 103 | 104 |
| 2 | 110 | 113 | 122 | 114 | 118 | 112 |
| 3 | 124 | 134 | 129 | 140 | 129 | - |
| 4 | 120 | 120 | 121 | 140 | 121 | 109 |
| 5 | 106 | 107 | 116 | 118 | 119 | 119 |
| 6 | 107 | 110 | 101 | 112 | 120 | 116 |
| 7 | 127 | 105 | 123 | 117 | 112 | 120 |
| 8 | 135 | 128 | 137 | 134 | 128 | 129 |
| 9 | 126 | 118 | 122 | 122 | 124 | 127 |
| 10 | 119 | 110 | 121 | 111 | 121 | 122 |
| 11 | 148 | 122 | 128 | 125 | 135 | 122 |
| $\bar{x}$ | 121 | 115 | 121 | 122 | 121 | 117 |
| SEM | $\pm 4.1$ | $\pm 3.3$ | $\pm 3.0$ | $\pm 3.6$ | $\pm 2.6$ | $\pm 2.5$ |

$\bar{x}$ = Mean

SEM = Standard Error

EQ = Equilibration

SUN = Supine Non-exercise

IN = Inverted Non-exercise

STN = Standing Non-exercise

Table 16. Systolic Blood Pressure (mmHg) of subjects exposed to supine, standing, and inverted postures under conditions of trunk flexion exercise. - Session V

| Subject | EQ | SUE 3 | EQ | STE 3 | EQ | IE 3 |
|---|---|---|---|---|---|---|
| 1 | 100 | 109 | 106 | 98 | 103 | 115 |
| 2 | 127 | 136 | 125 | 134 | 139 | 136 |
| 3 | 117 | 143 | 129 | 148 | 116 | 122 |
| 4 | 134 | 143 | 130 | 125 | 125 | 140 |
| 5 | 122 | 117 | 127 | 124 | 126 | 129 |
| 6 | 132 | 131 | 133 | 127 | 128 | 125 |
| 7 | 113 | 121 | 114 | 115 | 105 | 115 |
| 8 | - | 139 | 121 | 135 | 110 | 138 |
| 9 | 141 | 133 | 151 | 152 | 130 | 130 |
| 10 | 114 | 122 | 130 | 118 | 114 | 122 |
| 11 | 138 | 132 | 132 | 123 | 124 | 138 |
| $\bar{x}$ | 123 | 130 | 127 | 127 | 120 | 128 |
| SEM | ±3.8 | ±12.2 | ±3.5 | ±4.5 | ±3.4 | ±2.8 |

$\bar{x}$ = Mean

SEM = Standard Error

EQ = Equilibrium

SUE = Supine Exercise

STE = Standing Exercise

IE = Inverted Exercise

Table 17. Systolic Blood Pressure (mmHg) for subjects exposed to supine, inverted, and standing postures under conditions of trunk flexion exercise. - Session VI

| Subject | EQ | SUE 3 | EQ | IE 3 | EQ | STE 3 |
|---|---|---|---|---|---|---|
| 1 | 103 | 112 | 104 | 116 | 107 | 110 |
| 2 | 126 | 134 | 134 | 147 | 141 | 135 |
| 3 | 111 | 125 | 121 | 140 | 133 | 141 |
| 4 | 115 | 148 | 134 | 130 | 134 | 121 |
| 5 | 141 | 121 | 132 | 135 | 129 | 134 |
| 6 | 116 | 120 | 135 | 121 | 125 | 132 |
| 7 | 117 | 121 | 114 | 130 | 117 | 123 |
| 8 | 126 | 117 | 118 | 128 | 119 | 126 |
| 9 | 143 | 152 | 130 | 137 | 140 | 143 |
| 10 | 134 | 127 | 130 | 125 | 126 | 126 |
| 11 | 121 | 127 | 123 | 123 | 119 | 114 |
| $\bar{x}$ | 123 | 128 | 125 | 130 | 126 | 128 |
| SEM | $\pm 3.8$ | $\pm 3.8$ | $\pm 3.0$ | $\pm 2.8$ | $\pm 3.1$ | $\pm 3.1$ |

$\bar{x}$ = Mean

SEM = Standard Error

EQ = Equilibration

SUE = Supine Exercise

IE = Inverted Exercise

STE = Standing Exercise

Table 18. Third minute diastolic blood pressure (SBP) (mmHg) response of subjects exposed to supine, standing and inverted postures at rest and during 45$^o$ hip-flexion activity.

| | SUN | STN | IN | SUE | STE | IE |
|---|---|---|---|---|---|---|
| $\bar{x}$ | 65 | 77.5 | 69.5 | 74 | 79.5 | 73 |
| SEM | ±3.5 | ±3.5 | ±3.6 | ±2.8 | ±2.0 | ±2.3 |

x = Mean
SEm = Standard Error
SUN = Supine Non-Exercise
STE = Standing Non-Exercise
IN = Inverted Non-Exercise
SUE = Supine Exercise
STE = Standing Exercise
IE = Inverted Non-Exercise

Table 19. Diastolic Blood Pressure (mmHg) for subjects exposed to supine, standing, and inverted postures under passive conditions. - Session III

| Subject | EQ | SUN 3 | EQ | STN 3 | EQ | IN 3 |
|---|---|---|---|---|---|---|
| 1 | 69 | 59 | 72 | 83 | 76 | 62 |
| 2 | 85 | 83 | 95 | 91 | 94 | 72 |
| 3 | 54 | 51 | 51 | 52 | 63 | 47 |
| 4 | 77 | 81 | 77 | 67 | 79 | 73 |
| 5 | 72 | 58 | 68 | 74 | 70 | 79 |
| 6 | 68 | 58 | 70 | 75 | - | 61 |
| 7 | 56 | 54 | 56 | 66 | 58 | 63 |
| 8 | 85 | 71 | 87 | 95 | - | 75 |
| 9 | 86 | 75 | 83 | 97 | 74 | 97 |
| 10 | 83 | 70 | 74 | 85 | 76 | 70 |
| 11 | 82 | 67 | 76 | 78 | 84 | 65 |
| $\bar{x}$ | 74 | 66 | 74 | 78 | 73 | 69 |
| SEM | $\pm 3.5$ | $\pm 3.3$ | $\pm 3.8$ | $\pm 4.1$ | $\pm 3.1$ | $\pm 3.8$ |

$\bar{x}$ = Mean

SEM = Standard Error

EQ = Equilibration

SUN = Supine Non-exercise

STN = Standing Non-exercise

IN = Inverted Non-exercise

Table 20. Diastolic Blood Pressure (mmHg) for subjects exposed to supine, inverted, and standing postures under passive conditions. - Session IV

| Subject | EQ | SUN 3 | EQ | IN 3 | EQ | STN 3 |
|---|---|---|---|---|---|---|
| 1 | 61 | 54 | 63 | 58 | 66 | 74 |
| 2 | 57 | 51 | 55 | 53 | 61 | 65 |
| 3 | 83 | 76 | 87 | 79 | 92 | - |
| 4 | 84 | 64 | 78 | 87 | 80 | 89 |
| 5 | 75 | 52 | 73 | 68 | 72 | 74 |
| 6 | 58 | 59 | 59 | 82 | 87 | 62 |
| 7 | 80 | 68 | 79 | 67 | 82 | 87 |
| 8 | 91 | 82 | 87 | 79 | 83 | 87 |
| 9 | 69 | 66 | 72 | 67 | 66 | 80 |
| 10 | 67 | 51 | 77 | 56 | 64 | 76 |
| 11 | 91 | 82 | 82 | 71 | 87 | 87 |
| $\bar{x}$ | 74 | 64 | 74 | 70 | 76 | 77 |
| SEM | $\pm 3.8$ | $\pm 3.6$ | $\pm 3.3$ | $\pm 3.4$ | $\pm 3.3$ | $\pm 2.8$ |

$\bar{x}$ = Mean

SEM = Standard Error

EQ = Equilibration

SUN = Supine Non-exercise

IN = Inverted Non-exercise

STN = Standing Non-exercise

Table 21. Diastolic Blood Pressure (mmHg) for subjects exposed to supine, standing, and inverted postures under conditions of trunk flexion exercise. - Session V

| Subject | EQ | SUE 3 | EQ | STE 3 | EQ | IE 3 |
|---|---|---|---|---|---|---|
| 1 | 60 | 61 | 64 | 72 | 60 | 61 |
| 2 | 73 | 88 | 83 | 84 | 71 | 77 |
| 3 | 59 | 73 | 55 | 68 | 76 | 73 |
| 4 | 84 | 78 | 81 | 84 | 85 | 75 |
| 5 | 83 | 70 | 78 | 82 | 81 | 84 |
| 6 | 75 | 62 | 83 | 77 | 73 | 68 |
| 7 | 69 | 70 | 72 | 76 | 59 | 77 |
| 8 | - | 82 | 79 | 85 | 78 | 75 |
| 9 | 93 | 87 | 106 | 84 | 83 | 78 |
| 10 | 69 | 70 | 80 | 79 | 81 | 70 |
| 11 | 90 | 68 | 70 | 81 | 83 | 68 |
| $\bar{x}$ | 74 | 74 | 77 | 79 | 75 | 74 |
| SEM | $\pm 3.4$ | $\pm 2.8$ | $\pm 3.9$ | $\pm 1.7$ | $\pm 2.7$ | $\pm 2.2$ |

$\bar{x}$ = Mean

SEM = Standard Error

EQ = Equilibration

SUE = Supine Exercise

STE = Standing Exercise

IE = Inverted Exercise

Table 22. Diastolic Blood Pressure (mmHg) for subjects exposed to supine, inverted, and standing postures under passive conditions. Session VI

| Subject | EQ | SUE 3 | EQ | IE 3 | EQ | STE 3 |
|---|---|---|---|---|---|---|
| 1 | 68 | 63 | 65 | 65 | 66 | 76 |
| 2 | 72 | 88 | 78 | 80 | 87 | 81 |
| 3 | 58 | 59 | 52 | 68 | 51 | 68 |
| 4 | 82 | 83 | 80 | 88 | 69 | 77 |
| 5 | 77 | 66 | 77 | 77 | 79 | 83 |
| 6 | 66 | 65 | 72 | 62 | 69 | 72 |
| 7 | 63 | 71 | 70 | 68 | 68 | 76 |
| 8 | 85 | 74 | 88 | 70 | 89 | 86 |
| 9 | 88 | 82 | 90 | 78 | 98 | 97 |
| 10 | 81 | 67 | 75 | 71 | 80 | 77 |
| 11 | 77 | 64 | 84 | 64 | 83 | 84 |
| $\bar{x}$ | 74 | 71 | 76 | 72 | 76 | 80 |
| SEM | $\pm 2.9$ | $\pm 2.9$ | $\pm 3.3$ | $\pm 2.4$ | $\pm 4.0$ | $\pm 2.4$ |

$\bar{x}$ = Mean

SE = Standard Error

EQ = Equilibration

SUE = Supine Exercise

IE = Inverted Exercise

STE = Standing Exercise

Table 23. Third mean arterial pressure (MAP) (mmHg) response of subjects exposed to supine, standing and inverted postures at rest and during 45$^{0}$ hip-flexion activity.

| | SUN | STN | IN | SUE | STE | IE |
|---|---|---|---|---|---|---|
| $\underline{x}$ | 83 | 93 | 87 | 89 | 97 | 92 |
| SEM | ±3.2 | ±4.0 | ±3.3 | ±2.9 | ±2.5 | ±2.3 |

x = Mean

SE = Standard Error

SUN = Supine Non-Exercise

STE = Standing Non-Exercise

IN = Inverted Non-Exercise

SUE = Supine Exercise

STE = Standing Exercise

IE = Inverted Non-Exercise

Table 24. Mean Arterial Pressure (mmHg) of subjects exposed to supine, standing, and inverted postures under passive conditions. - Session III

| Subject | EQ | SUN 3 | EQ | STN 3 | EQ | IN 3 |
|---|---|---|---|---|---|---|
| 1 | 87 | 72 | 84 | 81 | 88 | 75 |
| 2 | 100 | 103 | 102 | 113 | 114 | 96 |
| 3 | 73 | 72 | 68 | 73 | 80 | 71 |
| 4 | 100 | 95 | 91 | 91 | 84 | 88 |
| 5 | 88 | 76 | 89 | 83 | 96 | 69 |
| 6 | 90 | 70 | 91 | 94 | - | 85 |
| 7 | 72 | 72 | 75 | 78 | 77 | 87 |
| 8 | 99 | 82 | 97 | 104 | - | 95 |
| 9 | 99 | 97 | 94 | 139 | 85 | 111 |
| 10 | 96 | 80 | 84 | 94 | 93 | 91 |
| 11 | 88 | 80 | 95 | 93 | 93 | 80 |
| $\bar{x}$ | 90 | 82 | 88 | 95 | 88 | 86 |
| SEM | $\pm3.1$ | $\pm3.5$ | $\pm3.0$ | $\pm5.6$ | $\pm3.2$ | $\pm3.7$ |

$\bar{x}$ = Mean

SEM = Standard Error

EQ = Equilibration

SUN = Supine Non-exercise

STN = Standing Non-exercise

IN = Inverted Non-exercise

Table 25. Mean Arterial Pressure (mmHg) of subjects exposed to supine, inverted, and standing postures under passive conditions. - Session IV

| Subject | EQ | SUN 3 | EQ | IN 3 | EQ | STN 3 |
|---|---|---|---|---|---|---|
| 1 | 80 | 74 | 82 | 80 | 79 | 82 |
| 2 | 107 | 103 | 102 | 94 | 106 | 98 |
| 3 | 72 | 87 | 74 | 86 | 88 | 78 |
| 4 | 96 | 97 | 94 | 103 | 102 | - |
| 5 | 94 | 78 | 94 | 100 | 86 | 97 |
| 6 | 86 | 78 | 83 | 86 | 87 | 93 |
| 7 | 79 | 75 | 78 | 80 | 79 | 79 |
| 8 | 87 | 84 | 94 | 79 | 89 | 99 |
| 9 | 102 | 92 | 101 | 100 | 95 | 99 |
| 10 | 96 | 78 | 81 | 83 | 81 | 96 |
| 11 | 92 | 77 | 93 | 76 | 78 | 96 |
| $\bar{x}$ | 90 | 84 | 89 | 88 | 88 | 92 |
| SEM | $\pm 3.2$ | $\pm 2.9$ | $\pm 2.9$ | $\pm 2.9$ | $\pm 2.8$ | $\pm 2.4$ |

$\bar{x}$ = Mean

SEM = Standard Error

EQ = Equilibration

SUN = Supine Non-exercise

IN = Inverted Non-exercise

STN = Standing Non-exercise

Table 26. Mean Arterial Pressure (mmHg) of subjects exposed to supine, standing, and inverted postures under conditions of trunk flexion exercise. - Session V

| Subject | EQ | SUE 3 | EQ | STE 3 | EQ | IE 3 |
|---|---|---|---|---|---|---|
| 1 | 75 | 73 | 75 | 77 | 78 | 83 |
| 2 | 92 | 100 | 102 | 94 | 86 | 94 |
| 3 | 81 | 105 | 79 | 94 | 33 | 97 |
| 4 | 98 | 98 | 93 | 91 | 92 | 94 |
| 5 | 102 | 90 | 100 | 96 | 87 | 89 |
| 6 | 87 | 85 | 93 | 90 | 85 | 77 |
| 7 | 81 | 84 | 86 | 91 | 81 | 91 |
| 8 | - | 93 | 94 | 108 | 91 | 94 |
| 9 | 114 | 94 | 120 | 110 | 104 | 88 |
| 10 | 84 | 88 | 96 | 93 | 97 | 94 |
| 11 | 100 | 81 | 81 | 96 | 101 | 90 |
| $\bar{x}$ | 91 | 90 | 93 | 95 | 85 | 90 |
| SEM | ±3.5 | ±2.8 | ±4.4 | ±2.7 | ±5.7 | ±1.8 |

x = Mean
SEM = Standard Error
EQ = Equilibration
SUE = Supine Exercise
STE = Standing Exercise
IE = Inverted Exercise

Table 27. Mean Arterial Pressure (mmHg) of subjects exposed to supine, inverted, and standing postures under conditions of trunk flexion exercise. - Session VI

| Subject | EQ | SUE 3 | EQ | IE 3 | EQ | STE 3 |
|---|---|---|---|---|---|---|
| 1 | 83 | 79 | 72 | 82 | 76 | 87 |
| 2 | 93 | 100 | 89 | 106 | 105 | 107 |
| 3 | 74 | 86 | 59 | 93 | 68 | 93 |
| 4 | 93 | 97 | 92 | 101 | 43 | 89 |
| 5 | 92 | 76 | 100 | 104 | 97 | 98 |
| 6 | 88 | 85 | 99 | 89 | 89 | 110 |
| 7 | 75 | 93 | 90 | 93 | 87 | 90 |
| 8 | 101 | 89 | 99 | 81 | 95 | 104 |
| 9 | 101 | 108 | 106 | 100 | 113 | 107 |
| 10 | 95 | 78 | 90 | 89 | 90 | 100 |
| 11 | 89 | 89 | 97 | 83 | 93 | 95 |
| $\bar{x}$ | 89 | 89 | 90 | 93 | 87 | 98 |
| SEM | $\pm 2.7$ | $\pm 3.0$ | $\pm 4.1$ | $\pm 2.7$ | $\pm 5.7$ | $\pm 2.4$ |

$\bar{x}$ = Mean

SE = Standard Error

EQ = Equilibration

SUE = Supine Exercise

IE = Inverted Exercise

STE = Standing Exercise

Table 28. Summary ANOVA for Assurance of Equilibration Prior to Exercise and Non-exercise Postural Change.

DEPENDENT VARIABLE: HEART RATE

| SOURCE | DF | SS | F VALUE | PR > F |
|---|---|---|---|---|
| ID | 10 | 11938.68 | 26.64 | 0.0001 |
| EQ(ID) | 22 | 903.5 | 0.92 | 0.58 |
| MODE(ID) | 33 | 6104.17 | 4.13 | .0001 |

DEPENDENT VARIABLE: SYSTOLIC BLOOD PRESSURE

| SOURCE | DF | SS | F VALUE | PR > F |
|---|---|---|---|---|
| ID | 10 | 6479.3544 | 11.77 | 0.0001 |
| EQ(ID) | 22 | 1159.66 | 0.96 | 0.53 |
| MODE(ID) | 33 | 4462.56 | 2.46 | 0.0011 |

DEPENDENT VARIABLE: DIASTOLIC BLOOD PRESSURE

| SOURCE | DF | SS | F VALUE | PR > F |
|---|---|---|---|---|
| ID | 10 | 10430.11 | 19.89 | 0.0001 |
| EQ(ID) | 22 | 1242.17 | 1.08 | 0.3947 |
| MODE(ID) | 33 | 3974.78 | 2.30 | 0.0023 |

DEPENDENT VARIABLE: MEAN ARTERIAL PRESSURE

| SOURCE | DF | SS | F VALUE | PR > F |
|---|---|---|---|---|
| ID | 10 | 10209.99 | 11.88 | 0.0001 |
| EQ(ID) | 22 | 1517.14 | 0.80 | 0.7112 |
| MODE(ID) | 33 | 2640.11 | 0.93 | 0.5802 |

Table 29. Summary ANOVA to "Rule Out" Ordering Effect

DEPENDENT VARIABLE: Oxygen Consumption($VO_2$)

| SOURCE | DF | SS | F VALUE | PR > F |
|---|---|---|---|---|
| ID | 1 | 3.62 | 0.37 | .55 |
| EX | 1 | 900.86 | 91.73 | .0001 |
| ORDER | 0 | 0.0 | . | . |

DEPENDENT VARIABLE: HEART RATE(HR)

| SOURCE | DF | SS | F VALUE | PR > F |
|---|---|---|---|---|
| ID | 1 | 135.31 | 0.16 | 0.6928 |
| EX | 1 | 9135.36 | 10.69 | 0.0022 |
| ORDER | 1 | 138.27 | .16 | 0.6896 |

DEPENDENT VARIABLE: SYSTOLIC BLOOD PRESSURE(mmHg)

| SOURCE | DF | SS | F VALUE | PR > F |
|---|---|---|---|---|
| ID | 1 | 4369.75 | 4.90 | 0.0328 |
| EX | 1 | 7816.66 | 8.78 | 0.0052 |
| ORDER | 1 | 801.98 | .90 | 0.3488 |

DEPENDENT VARIABLE: DIASTOLIC BLOOD PRESSURE(mmHg)

| SOURCE | DF | SS | F VALUE | PR > F |
|---|---|---|---|---|
| ID | 1 | 1513.84 | 2.61 | 0.1143 |
| EX | 1 | 1721.61 | 2.97 | 0.0928 |
| ORDER | 1 | 174.52 | 0.30 | 0.5864 |

Table 30. Summary ANOVA to "Rule Out" Ordering Effect in regard to Mean Arterial Pressure(MAP)

DEPENDENT VARIABLE: Mean Arterial Pressure(mmHg)

| SOURCE | DF | SS | F VALUE | PR > F |
|---|---|---|---|---|
| ID | 1 | 446.43 | 0.67 | 0.42 |
| EXERCISE | 1 | 2552.05 | 3.80 | 0.06 |
| ORDER | 1 | 19.45 | 0.03 | 0.87 |

Table 31. Summary ANOVA for Position and Mode(Exercise/Nonexercise)

DEPENDENT VARIABLE: Oxygen Consumption($VO_2$)

| SOURCE | DF | SS | F VALUE | $F_{CV}$ |
|---|---|---|---|---|
| ID | 21 | 47.88 | 2.98 | 19.46 |
| POSITION | 2 | 29.02 | 3.60 | 6.93 |
| MODE | 1 | 337.24 | 20.93 | 9.33 |
| POSITION * MODE | 2 | 16.11 | 2.59 | 6.93 |

DEPENDENT VARIABLE: Heart Rate(HR)

| SOURCE | DF | SS | F VALUE | $F_{CV}$ |
|---|---|---|---|---|
| ID | 21 | 3568.76 | 1.45 | 22.14 |
| POSITION | 2 | 6851.73 | 7.79 | 3.49 |
| MODE | 1 | 3054.73 | 3.47 | 4.35 |
| POSITION * MODE | 2 | 634.57 | .72 | 3.49 |

DEPENDENT VARIABLE: Systolic Blood Pressure(SBP)

| SOURCE | DF | SS | F VALUE | PR > F |
|---|---|---|---|---|
| POSITION | 2 | 225.15 | 1.75 | 0.18 |
| MODE | 1 | 2974.74 | 1.75 | 0.0001 |
| POSITION * MODE | 2 | 94.8] | 0.73 | 0.49 |

DEPENDENT VARIABLE: Diastolic Blood Pressure(DBP)

| SOURCE | DF | SS | F VALUE | PR> F |
|---|---|---|---|---|
| ID | 21 | 4059.97 | 5.96 | 0.0001 |
| POSITION | 2 | 2497.60 | 16.34 | 0.0001 |
| MODE | 1 | 550.76 | 8.09 | 0.0055 |
| POSITION * MODE | 2 | 166.91 | 1.23 | 0.2974 |

DEPENDENT VARIABLE: Mean Arterial Pressure(MAP)

| SOURCE | DF | SS | F VALUE | PR> F |
|---|---|---|---|---|
| ID | 21 | 5339.91 | 10.50 | 0.0001 |
| POSITION | 2 | 1401.62 | 13.21 | 0.0001 |
| MODE | 1 | 886.67 | 17.26 | 0.0001 |
| POSITION * MODE | 2 | 39.02 | 0.38 | 0.6848 |

Table 32. TUKEY'S STUDENTIZED RANGE (HSD) TEST FOR VARIABLES: OXYGEN CONSUMPTION, HEART RATE, SYSTOLIC BLOOD PRESSURE, DIASTOLIC BLOOD PRESSURE AND MEAN ARTERIAL PRESSURE.

| DEPENDENT MEASURE: | CONDITION: | STUDENTIZED RANGE$_{CV}$ | MEAN |
|---|---|---|---|
| Oxygen Consumption | Mode | 2.80 | |
| | Exercise | | 8.7 |
| | Rest | | 4.4 |
| | Position | 3.62 | |
| | Supine | | 6.9 |
| | Standing | | 5.4 |
| | Inverted | | 14.8 |
| Heart Rate | Mode | . | |
| | Exercise | | 82.8 |
| | Rest | | 70.5 |
| | Position | 3.41 | |
| | Supine | | 68.4 |
| | Standing | | 88.8 |
| | Inverted | | 73.0 |

| DEPENDENT MEASURE: | CONDITION: | STUDENTIZED RANGE$_{CV}$ | MEAN |
|---|---|---|---|
| Systolic Blood Pressure | | | |
| | Mode | 2.8 (min Significance =2.79) | |
| | Exercise | | 128.42 |
| | Rest | | 118.83 |
| | Position | 3.35 | |
| | Supine | | 123.25 |
| | Standing | | 122.25 |
| | Inverted | | 128.25 |
| Diastolic Blood Pressure | | | |
| | Mode | 2.8 (min Significance = 2.85) | |
| | Exercise | | 75.5 |
| | Rest | | 70.6 |
| | Position | 3.36 | |
| | Supine | | 69.5 |
| | Standing | | 78.5 |
| | Inverted | | 71.25 |
| Mean Arterial Pressure | | | |
| | Mode | 2.80 | |
| | Exercise | | 92.47 |
| | Rest | | 86.84 |
| | Position | 3.36 | |
| | Supine | | 86.0 |
| | Standing | | 95.0 |
| | Inverted | | 89.5 |

# Appendix C
# Informed Consent
# and
# Human Subjects Committee Approval

**HUMAN PERFORMANCE LABORATORY**

**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: Acute Hemodynamic Effects of Body Inversion With Exercise Using the Gravity Guider System®.

The purposes of this experiment include:

The purpose of the study is to investigate the acute hemodynamic (blood flow) effects of body inversion with exercise.

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

1) One graded exercise test which will be 85% of predicted HR maximum in nature and will last approximately 8-10 minutes.

2) Assumption of the supine, standing, and inverted positions for three minutes (2 trials).

3) Exercise (hip flexion from 0 to 45 ) in the supine, standing, and inverted position for three minutes (for 2 trials).

4) Finger tip samples of blood will be obtained once during each position.

5) A mask will be worn so the experimenters can measure pulmonary changes during the test.

6) Each trial shall be separated by one week for a total of four weeks.

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

1) Changes in heart rate and rhythm.
2) Extreme changes in blood pressure.
3) Fainting.
4) Very rare instances in heart attack during the graded exercise test.
5) Very rare cases of red sports (periorbital petechia) or discolorizations around the eyes or on the forehead which typically diminish when returned to the upright position.
6) Stroke - in which there have been no reported cases.
7) Infection.
8) Temporary ankle, knee or back pain.
9) Sinus congestion.
10) Abdominal soreness (from hip flexion exercise).

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

Determination of fitness level up to 85% of the age predicted heart rate maximum.

Measurement of hematocrit which is the volume percentage of red blood cells in whole blood.

Measurement of hemoglobin which is the oxygen-carrying pigment of the red blood cells.

Appropriate alternative procedures that might be advantageous to you include:

None.

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

I understand that I may abstain from participation in any part of the experimen 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 ______________________________
EPL Personnel

Project Director ____________________ Telephone ____________________

HPER Human Subjects Chairman Dr. Don Sebolt Telephone __________

Dr. Charles Waring, Chairman, Institutional Review Board for Research Involving Human Subjects. Phone

HUMAN PERFORMANCE LABORATORY

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

Pretest Screening for Exercise
During Various Postural Exposures

PART I. SELF-ADMINISTERED INTERVIEW

Name -____________________________ Date:____________________

Occupation____________________________________________

Age______________ Sex ______________

Campus Address __________________________________________

Home Address____________________________________________

Work Phone No. ________________ Home Phone No. ________________

Family Physician ____________________ City____________________

MEDICAL HISTORY

1. Indicate nature of condition* for male members of immediate family.

Personal__________________________________________

Grandfather

MATERNAL________________________________________

PATERNAL________________________________________

Father ________________________________________

Brother(s) ________________________________________

Uncle(s) ________________________________________

* Coronary arthery disease, angina pectoris, coronary thrombosis, rheumatic fever, cardiac enlargement, valvular heart disease, arrhythmia, other.

2. Have you ever experienced any of the following (please check the circumstances in which they occur):

______ chest pain ___at rest _____ at exertion ___ cold weather _____ emotion

______ chest pressure ___at rest _____ at exertion __)_cold weather _____ emotion

______ discomfort/pain in jaw ____ at rest _____ at exertion ___ cold weather __emotion

_____discomfprt/pain in teeth ____ at rest ____at exertion ____ cold weather___emotion

_____discomfort/pain in throat ___ at rest ____at exertion ____ cold weather___emotion

_____discomfort/pain in elbow ____ at rest ____at exertion ____ cold weather___emotion

_____discomfort/pain in wrist ____ at rest ____at exertion ____ cold weather___emotion

____ palpitations/skipped beats ___at rest ____at exertion ____ cold weather___emotion

3. Do you ever suffer motion sickness (please explain)? ______________________________

______________________________________________________________________.

4. Have you or do you suffer any eye, ear, nose, or throat condition that might preclude your being tilted to the upside down position? ____________________

______________________________________________________________________.

5. Have you ever suffered spontaneous nosebleeds, hearing loss, or pain in the face, head, ears, eyes, or throat? ______________________________________________

______________________________________________________________________.

6. Have you ever broken any bones(if yes, please explain)?______________________

______________________________________________________________________.

7. Do you suffer any back or joint problems(if yes, please explain)? ____________

______________________________________________________________________

______________________________________________________________________.

8. Please comment on any condition you might have that would prevent your participation in this study involving exercise in various postural exposures. ______________

______________________________________________________________________

______________________________________________________________________.

PART II. SCREENING MEASUREMENTS

Name____________________ Date____________________

STATION I

Age__________

Sex __________

Height__________cm

Weight__________kg

Body Composition

| Male | | Female | |
|---|---|---|---|
| Chest | ________ | Triceps | ________ |
| Abdomen | ________ | Supra-illiac | ________ |
| Thigh | ________ | Thigh | ________ |
| Total | ________ | Total | ________ |
| Computed Body Fat | ________% | Computed Body Fat | ________% |

STATION II

Blood Pressure ______/______ ______arm

1. Do you smoke tobacco products? yes [ ] no [ ]

If yes, complete the following.

2. What kind of tobacco products?

cigarettes [ ]
cigars [ ]
pipe [ ]

3. Over a typical week how much would you smoke?

| | | | |
|---|---|---|---|
| 1-2 cigarettes a day | [ ] | 1-2 cigars per day | [ ] |
| 3-5 cigarettes a day | [ ] | 3-4 cigars per day | [ ] |
| 6-9 cigarettes a day | [ ] | 5-6 cigars per day | [ ] |
| half a pack (10) a day | [ ] | 7-8 cigars per day | [ ] |
| 11-15 cigarettes a day | [ ] | 8-10 cigars per day | [ ] |
| 16-19 cigarettes a day | [ ] | more than 10 per day | [ ] |
| one pack (20) a day | [ ] | specify amount:________ | |
| 21-25 cigarettes a day | [ ] | | |
| 26-29 cigarettes a day | [ ] | | |
| one and a half pack a day | [ ] | | |
| 31-35 cigarettes a day | [ ] | | |
| 36-39 cigarettes a day | [ ] | | |
| two packs a day | [ ] | | |
| more than two packs a day | [ ] | | |
| Specify amount:________ | | | |

4. Your brand of cigarettes:________________
Your brand of cigars:________________

5. If you smoke a pipe, estimate the ounces of tobacco smoked per week.

1/8 oz. per week [ ]
1/4 oz. per week [ ]
1/2 oz. per week [ ]
3/4 oz. per week [ ]
one oz. per week [ ]
more than one oz. a week [ ]
specify amount:________
Brand(s):________________
________________

3. Have you ever had an exercise or fitness evaluation? _______ If yes, please explain______________________________________________

4. Are you taking any medications on a regular basis? No_________ Yes_________

5. If yes, please list any and all medications you are taking (both prescription and non-prescription drugs.)

| Name of Medication | Dosage | Doses per Day |
|---|---|---|
| ____________________ | ______ | __________ |
| ____________________ | ______ | __________ |
| ____________________ | ______ | __________ |
| ____________________ | ______ | __________ |

## EXERCISE/ACTIVITY HISTORY

1. Are you currently involved in a regular exercise program (3 days/week)? ______
2. Do you regularly walk or run one or more miles continuously? __________
   If yes, average number of miles you cover per workout or day:__________miles
   What is your average time per mile? ______________ minutes:seconds
3. Please check the following sports/activities in which you have participated over the past 6 months.

| Activity | Days/Week | Min/Day | Intensity Light | Intensity Moderate | Intensity Vigorous |
|---|---|---|---|---|---|
| basketball | ____ | ____ | ____ | ____ | ____ |
| bicycling | ____ | ____ | ____ | ____ | ____ |
| calisthenics | ____ | ____ | ____ | ____ | ____ |
| dancing | ____ | ____ | ____ | ____ | ____ |
| chopping wood | ____ | ____ | ____ | ____ | ____ |
| golf (without cart) | ____ | ____ | ____ | ____ | ____ |
| handball | ____ | ____ | ____ | ____ | ____ |
| mountain climbing/ hiking | ____ | ____ | ____ | ____ | ____ |
| racquetball | ____ | ____ | ____ | ____ | ____ |
| swimming | ____ | ____ | ____ | ____ | ____ |
| tennis | ____ | ____ | ____ | ____ | ____ |
| weight training | ____ | ____ | ____ | ____ | ____ |
| other__________ | ____ | ____ | ____ | ____ | ____ |
| other__________ | ____ | ____ | ____ | ____ | ____ |
| other__________ | ____ | ____ | ____ | ____ | ____ |

Principal Investigator(s) Thomas J. Ray Department HPER

Project Title Acute Hemodynamic Effects of Body Inversion with Exercise Using the*

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

1. The criteria for "expedited review" by the Institutional Review Board for a project involving the use of human subjects and with minimal risk* is one or more of the following. Please initial all applicable conditions and provide a substantiating statement of protocol.

*Gravity Guider System

- [ ] a. Collection of:
  - a) hair or nail clipping in a non-disfiguring manner;
  - b) deciduous teeth;
  - c) permanent teeth if patient care indicates need of extraction.
- [ ] b. Collection of excreta and external secretions: sweat, uncanulated saliva, placenta removed at delivery, amniotic fluid obtained at time of rupture of the membrane.
- [✓] c. Recording of data from subjects 18 years or older, using noninvasive procedures routinely employed in clinical practice. Exemption does not include exposure to electromagnetic radiation outside the visible range.
- [✓] d. Collection of blood samples by venipuncture (not exceeding 450 ml/8 week period, and no more than twice a week) from subjects 18 years or older, in good health and not pregnant.
- [ ] e. Collection of supra- and subgingival dental plaque and calculus, provided the procedure is no more invasive than routine scaling of the teeth.
- [ ] f. Voice readings.
- [✓] g. Moderate exercise by healthy volunteers.
- [ ] h. Study of existing data, documents, records, pathological specimens or diagnostic specimens.
- [ ] i. Research on drugs or devices for which an investigational exemption is not required.

2. If the project involves human subjects who are exposed to "more than minimal risk" and are not covered by the criteria above (a to i), the IRB review must involve the full IRB board. Please check if the research involves more than minimal risk** [ ] and provide a substantiating statement of protocol.

3. Human subjects would be involved in the proposed activity as either: Minors and/or Children* [ ], Fetuses [ ], Abortuses [ ], Pregnant Women [ ], Prisoners [ ], Mentally Retarded [ ], Mentally Disabled [ ].

Note that if children are involved in the research as human subjects, they may have to provide consent as well as their parents.

Whether or not the project may undergo "expedited review" or must be reviewed by the full Institutional Review Board, it is necessary that the required informed consent forms also be reviewed. These should be submitted with the proposal. However, if there is insufficient time to meet the sponsor's deadline, submittal can be delayed up to thirty days after submittal of the proposal without jeopardizing the IRB certification to the prospective sponsor.

* Minimal risk means that the risks of harm anticipated in the proposed research are not greater, considering the probability and magnitude, than those encountered in daily life or during performance of routine physical or psychological examinations or tests.

** Subject at risk is an individual who may be exposed to the possibility of injury as a consequence of participation as a subject in any research, development or related activity which departs from the application of those established and accepted methods necessary to meet his needs, or which increases the ordinary risks of daily life, including the recognized risks inherent in a chosen occupation or field of science.

This is to certify that the project identified above will be carried out as approved by the Human Subject Review Board, and will neither be modified nor carried out beyond the period approved below without express review and approval by the Board.

Signature: Principal Investigator/Date ______ Signature: Departmental Reviewer/Date ______

The Human Subjects Review Board has reviewed the protocol identified above, as it involves human subjects, and hereby approves the conduct of the project for ____ months, at which time the protocol must be resubmitted for approval to continue.

Signature: Board Chairman/Authorized Reviewer Date

**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
Thomas J. Ray

entitled Acute Hemodynamic Effects of Body Inversion with Exercise Using the Gravity Guider System

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 |
| | Date |

REQUEST FOR APPROVAL OF RESEARCH PROPOSAL
IN THE DIVISION OF HPER

Submitted to

Dr. Don Sebolt
Chairman, Division Human Subjects Committee and/or
Chairman, Institutional Review Board

by

Thomas J. Ray
Principal Investigator

TITLE: Acute Hemodynamic Effects of Body Inversion with Exercise Using the Gravity Guider System®

BACKGROUND/SCIENTIFIC JUSTIFICATION: Research on the acute hemodynamic effects of body inversion with exercise has proven inconclusive. John D. LeMarr and associates(1983) examined cardiovascular responses to passive inversion. Significant increases in systolic and diastolic blood pressure were observed. Recommendation for further study on exercise in the head down position was suggested. See attached research proposal entitled "Acute Hemodynamic Effects of Body Inversion with Exercise Using the Gravity Guider System.

PURPOSE(S): The purpose of this investigation is to examine the acute hemodynamic effects of exercise in the inverted position.

EXPERIMENTAL METHODS & PROCEDURES: The experimental methods and procedures shall be performed as described in the attached research proposal.

STATEMENT DESCRIBING LEVEL OF RISK TO SUBJECTS: Risks of any exercise test include: 1) changes in the rhythm of the heart, 2) extreme changes in blood pressure, 3) fainting, and 4) very rare instances of heart attack. Risks of the inversion of the body include: 1) changes in the rhythm of the heart, 2) extreme changes in blood pressure, 3) very rare cases of red spcts(periorbital petechia) or discolorizations around the eyes and on the forehead which diminished when returned to upright position and 4) cerebral vascular accident(CVA) - in which there have been no reported cases. The only risk from the blood sampling procedure is infection.

PROCEDURES TO MINIMIZE SUBJECT RISK (IF APPLICABLE): This study will use only physically active volunteers (ages 18-28 years) who have been found to tolerate inversion without complication* Research technicians include American College of Sports Medicine (ACSM) Certified Exercise Test Technologists. Heart rate and rhythm will be monitored electrocardiographically, continuously during and immediately post trial. Tests will terminate due to any of the ACSM termination criteria (ACSM, 1980). Blood tests will be obtained with finger tip samples by the principal investigator. The risks for this type sampling procedure are minimal when clinically aseptic techniques are used. The principal investigator and other technicians shall "spot" each subject during movement to ensure abrupt actions do not allow the subject to fall. Furthermore, the equipment is specifically designed to be stable during exercise in the inverted position.

RISK/BENEFIT RATIO (IF RISK PROJECT): The benefits of testing will be to provide the clinical community with information regarding the acute hemodynamic responses to exercise in the inverted position. Very recent research published by LeMarr and co-workers (1983) and Klatz and co-workers (1983) investigated inversion of the body using the equipment addressed in the attached research prospectus without complication.

* Those persons experiencing a systolic blood pressure of 175mm Hg. or greater and/or 110mm Hg. diastolic on inversion shall be excluded from the test.

INVESTIGATION INVOLVING HUMAN SUBJECTS

Principal Investigator(s) Thomas J. Ray Department Health, Phys. Educ. & Recr.
Project Title Acute Hemodynamic Effects of Body Inversion with Exercise Using the Gravity Guic System
Source of Support: Departmental Research ☐ Sponsored Research ☐ Proposal No. ________

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   c) permanent teeth if patient care indicates need of extraction.

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☐ c. Recording of data from subjects 18 years or older, using noninvasive procedures routinely employed in clinical practice. Exemption does not include exposure to electromagnetic radiation outside the visible range.

☐ d. Collection of blood samples by venipuncture (not exceeding 450 ml/8 week period, and no more than twice a week) from subjects 18 years or older, in good health and not pregnant.

☐ e. Collection of supra- and subgingival dental plaque and calculus, provided the procedure is no more invasive than routine scaling of the teeth.

☐ f. Voice readings.

☐ g. Moderate exercise by healthy volunteers.

☐ h. Study of existing data, documents, records, pathological specimens or diagnostic specimens.

☐ i. Research on drugs or devices for which an investigational exemption is not required.

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Signature: Principal Investigator/Date    Signature: Departmental Reviewer/Date

The Human Subjects Review Board has reviewed the protocol identified above, as it involves human subjects, and hereby approves the conduct of the project for ____ months, at which time the protocol must be resubmitted for approval to continue.

Signature: Board Chairman/Authorized Reviewer    Date

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