1-1-2004

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THE EFFECTS OF AN ELEVATED PRE-TEST HEART RATE ON A CARDIOVASCULAR TEST

by

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Bachelor of Science
Colorado State University-Pueblo
May 2002

A thesis submitted in partial fulfillment
of the requirements for the

Master of Science Degree in Exercise Physiology
School of Health and Human Sciences
Department of Kinesiology

Graduate College
University of Nevada, Las Vegas
May 2005

UNLV
UNIVERSITY OF NEVADA LAS VEGAS

Thesis Approval
The Graduate College
University of Nevada, Las Vegas

April 6, 2005

The Thesis prepared by

Jeffrey A. Dolgan

Entitled

The Effects of an Elevated Pre-Test Heart Rate on a Cardiovascular Test

is approved in partial fulfillment of the requirements for the degree of

Master of Science in Exercise Physiology

Examination Committee Chair

Dean of the Graduate College

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1017-53

ABSTRACT

The Effects of an Elevated Pre-Test Heart Rate on a Cardiovascular Test

by

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This study investigated the effects of an elevated Pre-Test Heart Rate (PTHR) on the results of the Physical Working Capacity Maximum (PWC max) test and Steady State Heart Rates (SSHR) during the two workloads that are used to predict PWC max. Fifteen subjects (ages 18-33 yrs, height 169.38 ± 9.77 cm, body mass 68.43 ± 12.53 kg, percent body fat 22.27 ± 7.40 %) participated in the study. PTHR was elevated using three methods prior to the administration of the PWC max test and the results compared to a criterion PWC max test that was completed after the subject was completely at rest. The three methods of elevating the PTHR were Exercise [EXER], Caffeine [CF], and Cold Pressor [CP]. The dependent measures were PWC max and the SSHRs of two workloads. The mean PWC max and standard deviation during the resting condition was 1368.73 ± 587.7 kilogram meters (kgm) and the averages for the resting conditions were; EXER-1358.8 ± 590.8 kgm, CF-1369.8 ±478.1 kgm, and CP-1308.2 ± 486.1 kgm. A repeated measures ANOVA produced an $f_{(3,32)}$ value of .839 and a p value of .4800 for PWC max.

This study demonstrated that a slightly elevated PTHR, whether elevated by exercise, caffeine or stress, did not significantly effect the results of a PWC max test.

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ACKNOWLEDGMENTS

I would like to give my sincerest appreciation to Dr. Lawrence A. Golding. Without his guidance and unwavering support, completion of this thesis would not have been possible. He has been a wonderful mentor, role model and friend during completion of this thesis.

I would like to extend my sincerest respect, admiration and appreciation to my committee members, Dr. John Young, Dr. Mack Rubley, and Dr. Carl Reiber. Their support and guidance throughout the completion of this study was constant and I would not have been able to complete it without their help.

Finally I would like to thank my wonderful family and friends, specifically, my parents, Kenneth and Katherine Dolgan and my sister, Lyndsay Dolgan. Their eternal love and constant support has motivated me in more ways than they will ever know. I would also like to extend a special thank you to John and Phyllis Pedote who have been like an extra set of parents during the completion of this study. I appreciate their support and friendship.

CHAPTER 1

INTRODUCTION

The effect of daily exercise on health and fitness is a major interest in exercise physiology. To quantify the changes in physical fitness that individuals make over time requires assessment by a physical fitness test battery. The physical fitness battery used in the University of Nevada, Las Vegas exercise physiology laboratory includes measurements of resting heart rate and blood pressure, somatotype photography, body composition, cardiorespiratory fitness, flexibility, and muscular strength and endurance tests. A concern of those administering the tests is whether not being completely rested, ingesting a caffeine drink, or being apprehensive affects the results of the cardiorespiratory test that is included in the test battery. How much does an individual's psychological and physiological state prior to the testing affect the results of a cardiorespiratory test? Several tests, including the 3-minute step test and the Physical Work Capacity Maximum (PWC max) test involve the use of heart rate to assess cardiorespiratory fitness. The question is: if a person reports to be tested with a slightly elevated resting heart rate, does this affect the results of the test? This is an important consideration because in order to accurately quantify the improvements that a subject makes and to evaluate the effectiveness of an exercise program, test scores must be reliable, and valid. If being completely rested prior to a cardiorespiratory test is important, then efforts should be made to control the factors affecting the results.

There are several environmental and psychological factors that could affect a pre-test heart rate. An increase in body temperature results in an increase in heart rate, while a decrease in body temperature results in a decrease heart rate (Guyton and Hall, 2000). de May et al. (1989) investigated the time course and nature of postprandial (after a meal) changes and found that heart rate increased 8.1 beats over resting after eating a 3100kj cold meal. Sleep deprivation may also cause an increase in resting heart rate (Lusardi et al., 1999). Other environmental factors effecting heart rate include wind, humidity and altitude. In a laboratory setting most of these factors can be controlled (except for altitude). Subjects can refrain from eating prior to testing. Likewise, other factors such as stimulant use and prior exercise are controllable prior to testing, but factors such as stress and apprehension are more difficult to control. However, increases in pre-test resting heart rate are often quite common due to a cup of coffee, hurrying to get to a scheduled laboratory appointment or being nervous about the test. In these cases, should a cardiorespiratory fitness test be postponed or cancelled?

Subjects are commonly asked to refrain from activities that could affect the results of a cardiovascular exercise test. These instructions commonly are that the subject arrives having:

- Not exercised 12 hours prior to the test
- Not consumed beverages containing caffeine or alcohol for 24 hours
- Gotten plenty of rest and being well relaxed for the test

These prerequisites hopefully prevent the results of a test being adversely affected. However, there is no published research that proves that any of these factors affect the results of an exercise test. Furthermore, it may be questioned as to how often subjects

actually adhere to the instructions. If subjects do not adhere to these precautionary measures, how significantly are the test results affected?

Purpose of the Study

The purpose of the study was to determine whether a slightly elevated pre-test heart rate significantly affected the results of a sub-maximal cardiovascular test (PWC max). A secondary purpose was to determine if a slightly elevated pre-test heart rate affected the steady state heart rates obtained during the Physical Working Capacity Maximum test. If the results were affected, which was more important: the effects of caffeine, emotional effects, or not being completely at rest?

Research Question

Does a slightly elevated pre-test heart rate significantly affect the results of a sub-maximal cardiovascular test?

Research Hypothesis

The research hypothesis was: Heart rate responses and sub-maximal test results are adversely effected by an elevated pre-test heart rate, regardless of the method used to induce the heart rate elevation.

The null hypothesis is: There is no difference in the test results when elevated pre-test heart rates exist.

Need for the Study

For several years physical fitness test administrators have attempted to control factors that may have an impact on a subject's performance in a testing session. Many subjects have been re-scheduled for testing because they failed to meet one or more of these prerequisites. It is assumed that an elevated pre-test heart rate will affect a PWC max test, which is dependent on heart rate. If these factors (caffeine, exercise, anxiety etc.) increase heart rate, will the increased heart rate alter the results of a sub-maximal cardiorespiratory test?

Definition of Terms

1. Pre-test heart rate (PTHR)-The resting heart rate that exists prior to a testing session.
2. Steady state heart rate (SSHR)-Refers to the plateau of heart rate at a constant workload.
3. Sub-maximal workload-An amount of exercise that produces a steady state heart rate that is below a person's maximal heart rate.
4. Body Composition – The proportions of fat, muscle, and bone making up the total body, usually expressed as a percent of body fat and percentage of lean body mass (Nieman, 1999)
5. Hypertension – a condition in which the blood pressure is elevated above systolic and diastolic measurements of 140 and 90 mmHg, respectively. (Nieman, 1999).

Limitations of Study

1. The subjects were males and females between 18-33 years old and the results cannot be inferred to older or younger age groups.
2. The subjects were of average physical fitness and were of average body composition and had normal hydration status; therefore the results may not be inferred to any other group (i.e. elite level athletes, those in a dehydrated state or obese individuals.)
3. The study only observed the effects of three methods of elevate pre-test heart rate (caffeine, exercise, and stress) on cardiovascular testing. There are a large number of other factors that could affect pre-test heart rate and the conclusions of this study cannot be inferred to these other causes.
4. The study only evaluated small changes in pre-test heart rate (5-10 beats per minute). The results can not be inferred to larger changes in elevated pre-test heart rate

Assumptions

1. The validity and reliability of the results relied on the subjects following the pre-test instructions. It is assumed that all of the instructions that were given to the subjects were followed and the subject verbally agreed that the instructions were followed.
2. All of the subjects reacted similarly to the cycle ergometer test and the three methods of elevating pre-exercise heart rate.

CHAPTER 2

RELATED LITERATURE

The dependent variables were the steady state heart rates that were measured during the final 15 seconds of the second and third minute of each stage of a sub-maximal cycle ergometer test and the PWC max that is predicted from these heart rates. An understanding of how heart rate is controlled at rest and during exercise is discussed below.

Control of Heart Rate and Blood Flow Through the Heart at Rest and During Exercise

At rest, the human heart pumps about 4-6 liters of blood per minute. This is referred to as resting cardiac output and is a product of the amount of blood pumped per contraction (stroke volume) times the number of times the heart contracts in a minute (heart rate). Cardiac output can increase four to seven times when a person is exercising. Guyton and Hall (2002), states that the two mechanisms by which the volume of blood pumped is regulated are (1) intrinsic cardiac regulation of pumping in response to changes in volume of blood flowing to the heart and (2) control of the heart rate by the autonomic nervous system.

The intrinsic ability of the heart to adapt to changing volumes of inflow of blood is the Frank-Starling mechanism (Guyton and Hall, 2000). The Frank-Starling mechanism states that the greater the heart muscle is stretched during filling, the greater the force of contraction and therefore, the greater the quantity of blood pumped into the aorta. When a larger volume of blood flows into the ventricles, ventricular myocardium is stretched, resulting in an increased contraction because the actin and myosin filaments within the myocardium are brought to a more optimal position for force production (Guyton and Hall, 2000). The result is that the ventricles, because of an increased force of pumping, automatically pumps a larger volume of blood into the arteries. A second factor that affects heart pumping is that the increased volume blood returning to the atria causes a stretch of the right atrial myocardium that directly increases the heart rate by 10-20 per cent (Guyton and Hall, 2000).

The pumping of the heart is controlled by the sympathetic and parasympathetic (vagus) nerves, which innervate the heart. Sympathetic stimulation can increase cardiac output more than 100 per cent over resting levels. The parasympathetic nerves, in contrast, can decrease cardiac output to almost zero by vagal (parasympathetic) stimulation (Guyton and Hall, 2000).

Sympathetic Stimulation of the Heart

Sympathetic stimulation can increase the heart rate in young adults from the normal resting rate of 70 beats per minute up to 180-200 beats per minute during exercise. Sympathetic stimulation also increases the force of heart contraction, thereby increasing the volume of blood pumped and increasing the ejection pressure. These increases cause cardiac output to increase two to three times resting levels (Guyton and Hall, 2000).

Inhibition of the sympathetic nervous system will decrease cardiac pumping by a moderate amount. When activity of the sympathetic nervous system is depressed below normal, heart rate and the strength of cardiac contraction are decreased. This results in cardiac pumping decreasing as much as 30 percent (Guyton and Hall, 2000).

The sympathetic nerves are distributed to all parts of the myocardium, with strong representation to the ventricular myocardium. When emotional or physical stressors such as fright, anxiety, excitement or exercise activate the sympathetic nervous system, norepinephrine is released at the cardiac synapses by sympathetic nerve fibers (Guyton and Hall, 2000), resulting in an increased heart rate. Although the mechanism of norepenepherine is somewhat questionable (Nobrega et al, 1993), it is believed that the hormone increases permeability of the fiber membrane to sodium and calcium resulting in an increased contractility of the heart. Sympathetic stimulation also increases contractility by enhancing calcium entry into the contractile cells.

Parasympathetic Stimulation of the Heart

Continuous parasympathetic stimulation of the heart slows the speed of the heart rate and very strong parasympathetic stimulation can stop the heartbeat completely for a few seconds (Guyton and Hall, 2000). Vagal stimulation also decreases the strength of heart contractions by 20 to 30 percent (Guyton and Hall, 2000). The parasympathetic fibers are distributed mainly to the atria and not to the ventricles where the power contraction of the heart occurs; therefore, vagal stimulation affects the heart by decreasing heart rate as opposed to decreasing the strength of contraction.

At rest, the vagus nerve also carries impulses to the sino-atrial and atrial-ventricular node; this is referred to as parasympathetic tone. A decrease in parasympathetic tone

causes an elevation in heart rate, while an increase in parasympathetic tone may cause the heart rate to slow (Guyton and Hall, 2000). During exercise, the initial increase in heart rate is due to withdrawal of parasympathetic tone, while at higher workloads, stimulation of the SA and AV nodes by the sympathetic nervous system causes the elevation in heart rate (Nobrega et Al 1993; Sedlock et al, 1983).

Elevated Pre-Test Heart Rate and Sub-Maximal Cardiovascular Testing

The effects of elevated pre-test heart rates on sub-maximal cardiovascular testing due to caffeine ingestion, psychological stress and apprehension and/or exercise have not been published. However, each of these three factors has been investigated regarding their effect on exercise. A discussion of these follows.

Caffeine and Heart Rate

There are several drugs that cause an increase in resting heart rate and these drugs are classified as stimulants. They include amphetamines (Benzedrine, Ephedrine, Methamphetamine), xanthenes such as caffeine and tea, and nicotine. Several food and beverage products and over-the-counter medicines contain caffeine. Most of these substances elevate heart rate.

The effect of caffeine on heart rate during exercise requires a discussion of the absorption, metabolism, excretion and mechanism of action of the stimulant. Caffeine is absorbed in the stomach and small intestine and its metabolism occurs mainly in the liver. Its metabolism begins with removal of one of three methyl groups from the xanthine ring

(see figure 1). The main metabolite of caffeine in humans is Paraxanthine, with Theophylline and Theobromine being produced in lesser quantities (Sinclair, 2000).

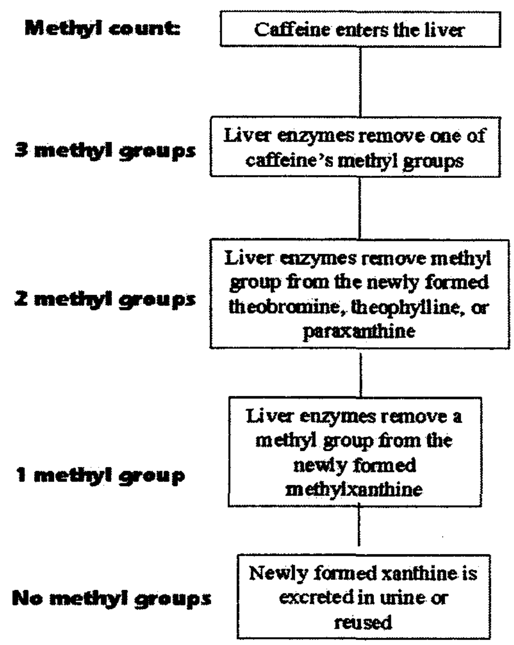

Figure 1: Caffeine metabolism (Sinclair, 2000)

There are several factors that can affect the metabolism of caffeine. These include genetics, prior ingestion of caffeine, gender, exercise, and diet (Sinclair, 2000). Chronic use of caffeine leads to an increased metabolism, which increases the ratio of the metabolites theophylline and paraxanthine (van Sorean et al, 1998). Caffeine is in urine as methylxanthine and methyluric acid and usually takes from 3 to 5 hours after ingestion (Spriet, 1995).

The published effects of caffeine supplementation on performance are too extensive for this review, however, it is important to understand the basic effects that the stimulant has on performance. Most of the studies focus on the effects of caffeine on prolonged performance; however, there are also some studies on short term-steady state exercise.

Jacobs et al. (2003) investigated the effect ingesting a combination of caffeine and ephedrine on muscular endurance as measured by a weight training circuit. The weight training circuit consisted of three supersets of an 80% 1 repetition-maximum (1rm) leg press, followed by a 70% 1rm bench press to exhaustion. Results showed that ephedrine caused significant increases in repetitions performed, however the caffeine-only-trial had no effect. Paton et al. (2001) investigated the effects of caffeine ingestion on 20-meter sprint performance. Using a double blind procedure, subjects performed repeated 20-meter sprints. The results showed that the effect of caffeine on sprint performance and fatigue was negligible. Bruce et al. (2000) had eight competitive oarsmen performed three experimental 2000-meter rows 1 hour after consuming either 6 or 9mg/kg of caffeine or a placebo. Both caffeine groups improved performance time and increased power, indicating that caffeine enhanced short-term endurance performance.

There are several suggested mechanisms of action for caffeine; the most common is the effect of antagonism of cell surface adenosine receptors (Sinclair, 2000). Adenosine receptors are members of the G-protein-coupled receptor family and mediate the multiple physiological effects of adenosine. Four adenosine receptors have been identified, characterized, and molecularly defined. These are A_1, A_{IIa}, A_{IIb} and A_3 (Olah et al, 1995). The activation of these receptors has several effects; it inhibits lypolysis, activates potassium channels, slows atrial-ventricular node conduction, inhibits neural firing, causes cerebral and peripheral vasodilatation, and inhibits inflammation. During exercise, the amount of adenosine available in the cells to activate these receptors is increased and the effects are increased (Sinclair, 2000). Therefore, caffeine causes

opposite effects of adenosine because it acts as an antagonist to block adenosine receptors.

A second effect of caffeine on exercise performance is its ability to increase mental alertness and stimulate the nervous system. Several studies have shown that rating of perceived exertion decreases during exercise after ingestion of caffeine (Costill, 1978, Cole, 1996). Motl et al. (2003) investigated the effects of a high dose of caffeine (10mg/kg body weight) on perceptions of leg muscle pain during moderate intensity cycling exercise and found that the perception of pain was significantly reduced in the caffeine group. This suggests that caffeine may increase endurance performance through its analgesic effects. Meussen (1995) suggested that a possible explanation of caffeine lowering the rating of perceived exertion is that through the blockade of adenosine receptors there is an increase in the release of excitatory neurotransmitters, which increases neuronal excitability. The neurotransmitters involved in the actions of caffeine include dopamine, GABA and seratonin. Dopamine is important in locomotor function (Meeusen, 1995). GABA is the primary inhibitory neurotransmitter in the central nervous system (Sinclair, 1995). Serotonin can be a mediator of fatigue in endurance athletes (Meeusen, 1995, Parry-Billings, 1990). Other effects of caffeine on physical performance include epinephrine release, decreased levels of potassium, cortisol release; increased levels of intracellular calcium; and inhibition of cAMP phosphodiesterase activity.

Although it is important to know the effects that caffeine has on performance and the mechanism of action of the caffeine, the purpose of the current study is only to

investigate the effects of caffeine on heart rate during sub-maximal cardiovascular testing.

Caffeine has several other effects on the cardiovascular system: its ingestion causes an increase in resting and exercise heart rate in subjects who have withdrawn from caffeine for 48 hours. Bell and McLellan, (2002) investigated the effects of caffeine ingestion on exercise performance 1, 3, and 6 hours after ingestion of caffeine. In their study, heart rate measurements were recorded during several different time periods and work levels in both users and non-users (Users were classified as consuming > 200mg/day and non-users were classified as consuming ≤ 50 mg/day/). In the non-user group at 5 minutes and 50% VO_2 max, heart rate was 3 beats per minute less than the control group. In the caffeine-user group the heart rate was 5 beats per minute higher than the control. Although the difference in heart rate was not significant, a difference of 3-5 beats could possible effect the progression and results of a sub-maximal test such as the Physical Work Capacity Maximum test. Studies have also shown that after caffeine ingestion there is a significant increase in both systolic (Kaminsky, 1998, Daniels, 1998) and diastolic blood pressure (Kaminsky, 1998). Daniels et al (1998) found that ingestion of 6mg/kg body weight of caffeine also altered the hemodynamic response to dynamic exercise, causing increases in forearm blood flow. Caffeine ingestion also has been shown to decrease blood flow to the myocardium during exercise (Edlund, 1995).

An additional consideration involving caffeine use is the effect of adapting to caffeine and the effect of adaptation on its action. Several studies have attempted to determine the difference between those that are accustomed to the caffeine and those that are not. Habitual caffeine intake may effect whether or not acute ingestion of caffeine improves

exercise performance (Spriet, 1995). Robertson et al. (1981) and Colton et al (1968) have demonstrated that caffeine users develop a tolerance to the effects of caffeine on resting blood pressure and heart rate. Fischer et al (1986) suggests that an explanation of the differences seen in studies on caffeine was due to the subject's caffeine familiarity. Caffeine users establish a tolerance to it's side effects. In contrast, Van Soren et al (1998) investigated the effects of a four-day caffeine withdrawal in habituated subjects on endurance and catecholamine response and found no effect on endurance as compared to those that did not withdrawal.

Pre-Test Anxiety and the Cold Pressor Test

Pre-test anxiety frequently presents a problem when comparing pre-test values such as blood pressure and heart rate as a baseline to post-test data. (Kaufman et al., 1987 and Coats et al., 1989). The PWC max test is frequently used to quantify the improvements that a subject makes in cardiorespiratory fitness and anxiety could cause an increased pre-test heart rate. Situations that cause pre-test anxiety are infinite and might include anything from an argument with a spouse, a difficult day at work, problems with children, or several other life situations. The laboratory setting or a doctor's office could cause feelings of anxiousness, especially when ones performance is being evaluated.

A subject who has pre-test anxiety might compromise test results. Anxiety and/or nervousness are difficult to control when testing subjects. Williams & Horvat (1995) suggested that pre-test anxiety is reduced simply by not communicating with the subject 30 minutes prior to a test. Artificial methods to cause a person to feel nervous or anxious are difficult to create. An investigator could bring a gun or a dangerous animal to the laboratory to attempt to induce nervousness, but this is unethical and possibly dangerous.

A test that results in anxiety responses that is commonly used in experimental studies is the Cold Pressor Test. The Cold Presser Test is widely applied in both biomedical, psychological and behavioral research to elicit a pain response and to create anxiety (Peckerman et al. 1991, Victor et al. 1987, Lepore et al. 1995). The test consists of submerging a body part (usually the hand or foot) into an ice bath of 4 degrees Celsius. The test may also be executed by applying a cold stimulus to the forehead. Peckerman et al. (1998), found that the foot and hand cold pressor test elicited similar results as the forehead Cold Pressor Test with respect to heart rate, systolic blood pressure and diastolic blood pressure.

The hand Cold Pressor Test is easy to apply and it offers a good method of raising heart rate similar to apprehension and stress, as well as exposing the subject to a cold environment. Victor et al. (1987) investigated the effects of the cold pressor test on muscle sympathetic nerve activity (MSNA) in humans. In 25 healthy subjects, arterial blood pressure, heart rate and MSNA were measured with microelectrodes inserted into a leg muscle (peroneal) during immersion of the hand in ice water for two minutes. Arterial pressure, heart rate and MSNA all increased significantly during the Cold Pressor Test. Heart rate peaked in the first 30 seconds and returned toward control values during the second minute. The authors concluded that the increase in heart rate appeared to be mediated by sympathetic activation rather than parasympathetic withdrawal and suggested that this is a response to the sensation of pain.

Exercise and Elevated Pre-Test Heart Rate

Exercising prior to a sub-maximal cardiovascular test could elevate the pre-test heart rate and change the results of the test. Normally, this exercise would be hurrying to the

test session or participating in exercise within 6 hours of the testing session. Short-term effects of exercise include an elevated heart rate, respiration rate and blood pressure. Pivarnik and Wilkerson (1988) reported excess in heart rate in 6 men for nearly 1 hour after a 60-minute exercise bout at 37, 56, or 75% of maximum oxygen consumption (VO_2 max). Gore & Withers (1990) found an elevation in heart rate for 1 hour after several bouts of dynamic exercise of various durations and intensities (less than 50% VO_2 max).

There have been no published studies on the effects of short-term low intensity exercise on elevated post exercise heart rates. However, there is a rapid increase in heart rate and cardiac output during the first few seconds of muscular exercise (Guyton and Hall, 2000). If the workload is constant, these cardiovascular parameters reach a steady-state plateau in 2-3 minutes. Recovery from short-term low intensity exercise occurs rather rapidly. Heart rate, stroke volume, and cardiac output all decrease towards resting levels within 10 minutes (Rowell, L, 1986). However, if an individual arrives to a laboratory immediately after participating in such low intensity exercise, an elevation of heart rate lasting 10 minutes could easily affect a sub-maximal cardio-respiratory test. Trained individuals tend to recover from this type of exercise faster than untrained individuals due to a more efficient cardiovascular response such as a lower exercise heart rate.

Effects of Dehydration on Heart-Rate

Dehydration can cause increases in rectal temperature and heart rate and cause decreases in sweat rate, oxygen consumption and exercise capacity when compared to conditions of normal hydration. An elevated heart rate in a dehydrated state is attributed to a reduced central blood volume, which leads to a lower ventricular filling pressure and

a reduction in stroke volume. The reduced stroke volume is not offset by a proportional increase in heart rate; consequently, the cardiac output and arterial blood pressure decline (Gonzalez-Alonso et al., 1994) For each liter of sweat-loss dehydration, the exercise heart rate becomes elevated by 8 beats per minute with a corresponding 1.0 L per minute decrease in cardiac output (Coyle et Al., 1992).

Relationship Between Heart rate and Oxygen Consumption

Heart rate and oxygen uptake increase in a linear fashion with the work rate during dynamic exercise to the point of maximum exertion (ACSM, 2001). Thus, maximum oxygen consumption (VO_2 max) may be estimated using the relation between heart rate and oxygen consumption (VO_2) without subjecting an individual to maximum levels of physical stress. During sub-maximal exercise testing, predetermined workloads are used to elicit a steady state of exertion (plateau of heart rate and VO_2).

Sub-Maximal Cardiovascular Testing

The procedures for the sub-maximal cycle ergometry test used in this study are based on the principle of all sub-maximal cycle tests used to predict aerobic fitness, namely that a linear relationship exists between work load and heart rate as is described above. This procedure was adapted from the Y's Way to Physical Fitness (Golding, L., Meyers, C., and Sinning, W., 1989)

The PWC max test was designed to establish the relationship between heart rate and workload for the subject being tested. In this protocol, two heart rates between 110 to

150 beats per minute are used, then they are jointed and the line represents the subject's line between heart rate and work. Many external stimuli such as talking or nervousness can affect heart rate when it is lower than 110 beats per minute, thus to establish this line only heart rates above 110 beats per minute are used. The linearity of heart rate increases until it reaches a plateau with an increase of workload, which signals maximum heart rate. Maximal heart rate is commonly predicted with the equation 220-age (Robinson et. al, 1938). Although max heart rate is essentially a function of age, it is assumed that most people being tested will be less than 70 years of age so the top limit of linearity used is 150 beats per minute (220-70 = 150).

Once this line between heart rate and work -load is determined, it is extrapolated to a point where it meets the predicted maximum heart rate. A perpendicular line is dropped from that point to the base line, which represents the predicted workload at maximum heart rate. Since heart rate and oxygen consumption also have a linear relationship, maximal oxygen consumption can also be predicted from the maximum workload and heart rate (see Appendix B5 for PWC max graph).

As an alternative, an equation has been developed to calculate an individuals PWC max. The equation is as follows:

$$\text{PWC Max} = \frac{(220\text{-age})\text{-HR2 } [(\text{HR2-HR1})/(\text{WL2-WL1}) *\text{WL2})]}{(\text{HR1-HR2/WL2-WL1})}$$

Where: Age = Age In Years
HR = Heart Rate
HR1=HR at the first WL used
HR2=HR at the second WL used
WL1= First Workload causing a HR above 110 but below 150
WL2= Second Workload causing a HR above 110 but below 150

PWC max Test Protocol

The test begins with a short warm-up of 3-4 minutes at a low resistance level. Once the warm-up is completed, a metronome is set at 100 beats per minute to insure that the subject keeps pace at 50 revolutions per minute. The circumference of the flywheel on the Monark ergometer is 6 meters, therefore the workload that a subject will be working at is a product of distance (flywheel circumference) multiplied by the revolutions per minute (rpm) multiplied by the amount of resistance applied to the ergometer's flywheel (DxSxR). The test begins with the lowest resistance of .5 kg (or 150 kilogram meters per minute-.5 Kg x 6 m x 50 rpm/minute =150 kgm/minute). The subject rides at this resistance level until steady state heart rate is reached (a minimum of 3 minutes), with the goal of two consecutive minutes eliciting heart rates that differ by less than 5 beats per minute. This is then accepted as SSHR After the initial stage, the test progresses according to the following workload chart.

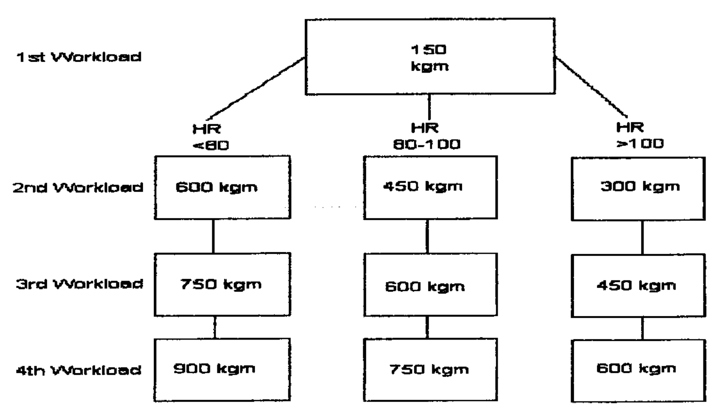

Figure 2- Progression of workloads for PWC max test Golding, L.A. (2000).

As can be seen in the chart, if the first stage elicits a steady state heart rate below 80 beats per minute (bpm), indicating that the workload was relatively easy, and then the second workload applied is 2 kilo-grams (600 kgm). If the steady state heart rate is between 80-100 bpm, then the second workload applied is 1.5 Kg (450 kgm). If the steady state heart rate is greater than 100 bpm, then the second workload that is applied is 1 Kg (300 kgm). The second stage is once again completed until two separate minutes elicit a steady state heart rate that differs less then 5 beats per minute. If the steady state heart rates from stage 1 and 2 are not above 110 beats per minute then a third stage is needed. The workload increases by .5 kg (150 kgm) with the need for each additional stage on the ergometer. The test is considered complete once two separate workloads elicit steady state heart rates that are greater than 110 beats per minute and less than 150 beats per minute.

Assumptions of Sub-Maximal Exercise Tests.

Sub-maximal exercise tests assume a steady-state HR at each exercise intensity as well as a linear relationship between heart rate, oxygen uptake and work intensity. While this is true for light to moderate workloads, the relationship between oxygen uptake and work becomes curvilinear at higher workloads.

Another assumption of sub-maximal testing is that the mechanical efficiency during cycling or treadmill exercise is constant for all individuals. However, an individual with poor mechanical efficiency while cycling has a higher sub-maximal heart rate at the given workload, and the actual maximum oxygen consumption (VO_2max) is underestimated (Mcardle, Katch and Katch, 1996). As a result, VO_2max predicted by

sub-maximal exercise tests tends to be overestimated for highly trained individuals and underestimated for untrained, sedentary individuals.

Sub-maximal tests also assume that the maximum heart rate (HR max) for individuals of a given age is similar. The HR max, however, has been shown to vary as much as 11 beats per minute, even after controlling for variability due to age and training status (Londeree and Moeschberger, 1984). For sub-maximal tests, the HR max is estimated from age. The equation HR max = 220-age, yields a low estimate of the maximum heart rate, while the equation HR max = 210 – (.05 x age), gives a high estimate of maximum heart rate (ACSM, 1995). The maximum heart rate of approximately 5-7% of men and women is more than 15 b.p.m. less than their age predicted HR max, while 9-13% have HR max values that exceed their age-predicted HR max by more than 15 b.p.m. (Whaley et al. 1992). Due to individual variability in HR max, as well as the inaccuracy of using age-predicted HR max, a 10-15% error can be expected when estimating a person's maximal oxygen consumption from a sub-maximal test (ACSM, 1995).

CHAPTER 3

METHODOLOGY

Subjects

The University of Nevada, Las Vegas Human Subjects Institutional Review Board (IRB) approved this study (see Appendix-B3). 15 subjects (6 male, 9 female, 25.33 yrs, 1.69 m, 68.43 Kg) volunteered for the study. Subjects were between the ages of 18 and 33 years old and were all screened for hypertension prior to committing to the study, those with a resting blood pressure of ≥ 140/90 mmHg (Nieman, 1999) were eliminated from the subject pool. Subjects read and signed an informed consent form prior to any measurements or information being collected (see Appendix B1). Caffeine usage was not used as a screening criteria, however subjects were instructed to withdraw from using caffeine for 24 hours prior to each testing session. Subjects who met the criteria of the study, who signed the informed consent, and were not at risk for aerobic activities, were asked to volunteer for 5 testing sessions lasting one hour each. The first day was an orientation day in which risk assessment was completed using a Physical Activity Readiness Questionnaire (Par-Q see appendix B4). In addition, anthropometric measurements including height, weight, and body composition were measured, resting blood pressure was measured and recorded and instructions for the study were given to the subject. The following four testing sessions consisted of the completion of the PWCmax test after one of four

experimental methods were applied. The four testing sessions consisted of one completely rested condition and three methods of elevating the pre-exercise heart rate. The completely resting condition was the criterion method and the other methods were compared to it. The three remaining sessions included the cold pressor test, pre-exercise, and caffeine ingestion, the goal of these three methods was to raise the pre test heart rate 10-15 beats per minute prior to the administration of the PWC max test. Table 1 presents the subject's physical characteristics.

Table 1: Physical characteristics of test subjects

Subjects	Gender	Age (Yrs.)	Weight (Kg.)	Height (Cm.)	% Body Fat	Resting Blood Pressure (mmHg)
1	F	24	58.41	164	20.93	100/70
2	F	18	69.09	164.3	34.16	100/72
3	F	28	63.86	177	21.84	104/68
4	F	27	61.36	167	23.64	124/90
5	F	29	59.66	164	19.25	100/70
6	F	20	57.73	154	28.4	118/80
7	F	21	61.82	158.5	29.86	122/70
8	F	22	50.2	162.5	24.62	104/60
9	F	33	58.18	159.5	31.41	120/90
Mean	F	24.67	60.03	163.42	26.01	110/74
SD	F	4.9	5.12	6.4	5.15	10/10
10	M	32	72.73	175	9.34	120/78
11	M	18	75.5	172.4	18	120/90
12	M	25	81.7	181.75	26.6	120/74
13	M	32	98.18	175.5	27.71	122/80
14	M	26	79.55	190	16.2	120/90
15	M	25	78.5	175.2	9.52	118/80
Mean	M	26.33	81.03	178.31	17.9	120/82
SD	M	5.24	8.97	6.51	7.98	1/7
Mean Total (m+f)		25.33	68.43	169.38	22.27	114/77
SD Total		±4.92	±12.53	±9.77	±7.402	±9/9

<u>Purpose/Methods</u>

This study determined the effects that a slightly elevated pre-test heart rate had the results of the Physical Working Capacity Maximum test. The rationale was that laboratories assessing aerobic performance of subjects routinely follow certain procedures prior to assessment. Typically these requirements are:

- No exercise for 12 hours prior to testing
- No food intake for 6 hours prior to testing
- Adequate sleep/rest the night before assessment (approximately 8 hours)
- Ingesting no drink or medication containing caffeine or any other stimulant for at least 24 hours prior to testing

At the time of the assessment subjects are usually asked to sit or lie down for 10 minutes to ensure that the subject will be completely at rest when starting the assessment. In addition, the test protocol is thoroughly explained to the subject in an attempt to reduce any unnecessary apprehension and/or nervousness.

The purpose of these prerequisites are usually explained as being necessary to control resting heart rate prior to testing so that heart rate (and oxygen consumption) will not be influenced by anything but the test being administered. It is believed that the test results will then be accurate, reliable, and valid.

Many subjects have been rescheduled for testing because they failed to meet one or more of the above prerequisites. Subjects who are obviously appearing apprehensive may even be given a “trial run for familiarization” and then rescheduled.

However, there is no research data to support the claims that a slightly elevated pre-test heart rate detrimentally affects the results of an aerobic test.

The study investigated whether changing the pre-test heart rate by three different, but typical means, affected the results of the Physical Working Capacity maximum test (PWC max-see description of test below).

Methods/Design

The study was a one-way-within subject's design. Three methods of slightly elevating pre-test heart rate were assessed to determine the effects that the slightly elevated pre-test heart rate had the results of the PWC max test. The first condition (rested) consisted of a completely rested pre-test heart rate. This was the criterion method that was considered the baseline to which the other three methods were compared. The second condition (cold-pressor) consisted of the subject submerging the left arm into a 4 degree Celsius ice bath for 30 seconds to slightly elevate pre-test heart rate. The third condition (exercise) consisted of the subject performing a short treadmill walk at 3 miles per hour and 0% grade that resulted in an elevated pre-test heart rate. The fourth condition (caffeine) consisted of the subject consuming 2, 200mg over-the-counter caffeine pills one hour prior to the test so that the pre-test heart rate was elevated 5-10 beats above the resting level. The dependent measures were the predicted Physical Work Capacity maximum value and the steady state heart rates used in the prediction calculation. Data were collected during 4 days that were each separated by 48 to 72 hours in which one of the four methods was used, starting with the resting condition. The subsequent three methods of elevating pre-exercise

heart rate were randomized. Rating of perceived exertion (RPE) data were also collected to quantify the effects of each of the four separate methods on the perceived work level of the subject, however RPE data was not statistically analyzed.

Test Conditions

The following briefly summarizes the test conditions used for the experimental portion of the study. A more detailed explanation of each method of elevating pre-test heart rate can be found in the testing day procedures. Each method was separately applied prior to the PWC max testing sessions. The first method was used as the criterion method and was completed before the three experimental methods. The three experimental methods were completed in random order.

1. The first method consisted of a completely resting heart rate. This method was considered the criterion method that produced the most accurate results from the PWC max test. The measurements of steady state heart rates and the predicted PWC max were used as baseline comparisons for the other three methods. Once the subject had rested for 10 minutes, the PWC max was completed as explained in the test protocol.

2. The second method consisted of the subject's pre-test heart rate being slightly elevated through the use of the cold presser test and was used to represent a psychological stress that could occur prior to a testing session. After a 10-minute rest period, the subject positioned him or herself on the cycle ergometer and immersed the left arm into a 4-degree Celsius ice bath until a spike in heart rate was noticed

(Peckerman et al., 1998). After the increase in heart rate was recorded, the PWC max test was completed as described in the test protocol.

3. The third method slightly elevated the pre-test heart rate through the use of a short treadmill walk. This method was used to represent a subject reporting to be tested after hurrying for the appointment or having exercised earlier in the day. After a 10-minute supine resting period that allowed the heart rate to reach a lowest resting rate, the subject mounted the treadmill. The subject walked at a self -selected pace until the heart rate increased 10-15 beats. If the pace did not elevate the heart rate, the grade on the treadmill was increased until the desired heart rate was elicited and recorded. The subject mounted the cycle ergometer and the PWC max test was completed as described in the protocol.

4. The fourth method required the subject to consume two 200-mg caffeine pills one-hour prior to the experimental protocol. The subjects were given two 200mg no-doze caffeine pills (equivalent to four cups of regular drip coffee) during the initial orientation and asked to take these pills one hour prior to arriving for this session. As before, the subject rested for 10 minutes. The pre-exercise heart rate was recorded and the PWC max test was completed as described in the test protocol.

Instrumentation and Methods of Use

The instrumentation listed below was used during the orientation session:

- Sphygmomanometer and Stethoscope- Resting blood pressure was measured from the left upper arm according to American Heart Association standards. A systolic and 5th phase diastolic blood pressure was taken during the orientation day using a manual mercury blood pressure sphygmomanometer (model TRIMLINE by PyMah Corporation[1]) and a stethoscope. Resting heart rate was measured with the stethoscope for 60 seconds and recorded.
- Scale- Weight in kilograms was measured using a calibrated physicians scale. Subject's removed shoes and any excess clothing and jewelry.
- Stadiometer- Height in centimeters was measured using a wall-mounted stadiometer. Height was measured after the subject had removed his or her shoes.

The instrumentation listed below was used with all four experimental conditions:

- Polar Heart Rate Monitor - A Polar Heart Rate Monitor, model number A1[2] was used to monitor heart rate throughout each testing session to support the electro-cardiograph. The heart rate monitor was fitted around the upper torso according to manufacturer instructions so that the transmitter electrode was in the center of the chest at the level of the xyphoid process. The receiver watch was placed around the subject's right wrist. The Polar Heart Rate Monitor was not used for data collection.
- Electro-cardiograph - The EKG used in the study was a single channel Hewlett Packard model 1500 B[3].

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[1] PyMah Corporation, Somerville, New Jersey, USA.
[2] Polar
[3] Hewlit Packard,

During the time that the subject was resting, electrode sites were cleaned with alcohol. If hair removal was necessary, it was removed with a new disposable razor, and shaving cream. The right-arm electrode (negative) was placed on the manubrium, the left -arm electrode (positive) was placed in the V4 position, and the right leg electrode (ground) was placed on the right lower quadrant of the abdomen (see figure 3 below). The EKG was recorded as Lead I.

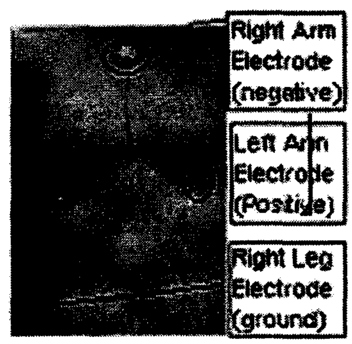

Figure 3: Placement of EKG Electrodes

After the EKG had been fitted, the subject lay quietly for 10- minutes to allow the pre-test heart rate to reach its lowest level. After the resting period, a 30-second pre-test heart rate was counted and recorded on the EKG.

The EKG was also used to count and record heart rate any time that a heart rate measurement was needed: during the PWC max test, treadmill test, cold pressor test, and resting heart rate.

- Stationary Cycle Ergometer-The PWC max test used a Monark stationary cycle ergometer[4] during all testing conditions. During the orientation session,

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[4] Monark, Stockholm Sweden

familiarization with the test included determining seat height with each subject. The subject sat on the cycle seat and the height was adjusted so that when the leg was in the down position, the knee had 5 degrees of flexion. The subject was then instructed to begin pedaling with no resistance on the bike. The cycle ergometer was then calibrated by making sure that the resistance indicator on the bike read zero. If the resistance indicator did not read zero, necessary adjustments were made according to the manufacturers suggestions.

1. Workloads

   One complete revolution of the Monark ergometer flywheel, if it were in contact with the floor, would move the flywheel 6 meters. Therefore, if the resistance was set at 1 kilogram the work done is 300 kilogram meters (1kg x 6m x 50 revolutions/min = 300 kgm/min).

- Metronome –A Franz quarts metronome[5] (model XB-700) was used to ensure that the subject maintained a cadence of 50 revolutions per minute. For subject ease, the metronome was set at 100 beats per minute and with each beat a leg was moving into a down position at a pace of 50 revolutions per minute. The metronome was calibrated prior to each use by counting the number of ticks in one minute and making adjustments as needed. The metronome was turned on after the subject had taken position on the cycle.
- Skinfold Calipers – Percent body fat was determined using Lange[6] skinfold calipers, measuring four skinfold sites and using the Jackson and Pollock sum of four skinfolds equation. The Jackson and Pollock formula has a .094 correlation with underwater

[5] Franz Manufacturing Company, New Haven, Connecticut, USA
[6] Beta Technology Incorporated, Cambridge Maryland

weighing (Golding, 2000). All skinfold measurements were taken on the right side of the body. The four skinfold measurements were:

a. Abdomen- vertical fold- 1 inch to the right of the umbilicus
b. Ilium- Diagonal fold- above the crest of the ilium on the midaxillary line
c. Thigh- vertical fold- midway between the top of the patella and the groin line
d. Triceps- vertical fold- back of the upper arm midway between the acromian and olecranon processes.

The Jackson and Pollock sum of 4 skinfold equation for males and females is as follows.

Males: Percent Fat= $.29669\ (\sum 4) -.0005\ (\sum 4^2) + .15845\ (AGE) - 5.76377$

Females: Percent Fat= $.29669\ (\sum 4) - .00043\ (\sum 4^2) + .02963\ (AGE) + 1.4072$

The standard error for the male equation is 3.49% with an R= .901 and for the female equation is 3.89% with an R= .896 (Golding, 2000).

The Lange caliper meets the Food and Nutrition Board of the National Research Council of the United States standards (Golding, 2000).

- Rating of Perceived Exertion Chart- Rating of perceived exertion was taken during the final 15 seconds of each workload during the PWC max test. A category scale Borg 6-20 RPE chart was used for the recording of this value (Noble et al, 1983). Instructions on using the Borg scale were in accordance with G. Borg's perceived Exertion and Pain Scales (Borg, 1998). The subject pointed to the appropriate number that represented his or her overall feeling of exertion on RPE chart.
- Timer – A Cra Lab[7] universal 750 watt timer (model 167) was used to measure all timing during the study including rest time and stages during the PWC max test.

[7] DIMCO-GREY Company, Dayton, Ohio, USA

The following instrumentation was used only in the condition it was pertinent to:

- Treadmill -During the pre-exercise condition, a Quinton instruments[8] (model 24-72) treadmill was used to elevate the pre-test heart rate. The treadmill had a range of 0-20% grade and 0-14 miles per hour.
- Ice Bucket – During the cold pressor condition, an ice and water mixture of 4 degrees Celsius was used. This ice mixture was placed into a 10-gallon water container. A thermometer was used to ensure the temperature of the ice mixture.
- Caffeine Pills – Each subject was given two 200mg over the counter caffeine pills. The pills used were NoDoz[9]. Subjects were told to consume these pills one hour prior to arriving to the laboratory.

Procedures

Subjects were asked to report to the Exercise Physiology Laboratory for five separate, one-hour data collection sessions.

Day 1 - Orientation Day Procedures

The first session was designed to be an orientation day and a time to complete resting measurements. The studies purpose and procedures were explained, risk assessment was completed, and several anthropometric measurements were taken. Upon entering the lab, participants read the informed consent. They asked questions until they thoroughly understood the study and the testing protocol. The subjects then signed the informed consent document. This was done prior to any measurements being taken or data being collected. A self-rating health screening document (Par-Q) was completed and a resting

[8] Quinton Insturments, Seattle, Washington, USA
[9] Bristol-Myers Squibb Company, New York, New York, USA

blood-pressure measurement was taken. The Par-Q was designed to identify if physical activity might be inappropriate for an individual or if an individual might need medical screening prior to engaging in physical activity. Resting blood pressure was measured and recorded from the left upper arm according to American Heart Association standards and resting heart rate was measured for 60 seconds using a stethoscope. The Par-Q documents were filed with other subject documents and data after it was determined that the individual qualified as a subject and was not at risk for physical activity testing or participation. If the subject answered yes to any question on the PAR-Q or if his or her blood pressure was over 140/90 he or she was excluded from the subject pool and the PAR-Q document was destroyed

After the risk assessment was complete, anthropometric measurements were taken including; height as measured by a wall-mounted stadiometer, weight, as measured by a calibrated physicians scale, and body composition using Lange skinfold calipers and the Jackson and Pollock sum of four skinfold equation. Subjects were also given a list of instructions to follow prior to the four testing sessions. These instructions were as follows:

1. Do not eat in the 6 hours prior to the testing session, but drink normal amounts of water.
2. Do not consume caffeine or alcohol containing beverages for 48 hours prior to the testing session.
3. Arrive at the laboratory well relaxed and rested, after a good night of sleep (approximately 8 hours).
4. Do not exercise for 12 hours prior to testing.

5. Arrive at least 20 minutes prior to testing so that heart rate and blood pressure can reach the lowest resting level.

Testing Day Procedures

Day 2-Resting PWC max Test

Since the completely rested condition was the criterion method, it was always completed first. This was done to ensure that the criterion results for the PWC max were reliable. It was assumed that if the subject followed all of the pre-test instructions and rested prior to the assessment that the results of the criterion test would be representative of the correct and valid results. The subject arrived at the laboratory and lay on a padded treatment table for 10 minutes to allow the heart rate to reach a lowest resting level. The EKG electrodes were placed during this time. After the subject had rested for 10 minutes, a 30 second pre-test heart rate was measured with the EKG. The subject then sat on the cycle ergometer.

The seat height was adjusted and the test again explained to the subject. The metronome was started and the subject was instructed to begin cycling in cadence with the metronome (100 beats per minute). Once it was determined that the subject was pedaling at the correct cadence, the PWC max test procedure began.

The first workload, which was always 150kgm, was applied to the flywheel. The subject rode at this level until a steady state heart rate was reached (a minimum of 3 minutes).

The remainder of the PWC max test progressed according to the PWC max progression chart as listed in the literature review section (figure 2). The subject

continued to ride until two consecutive stages (work-loads) elicited steady state heart rates that were above 110 beats per minute but below 150 beats per minute.

The subjects exercise heart rate was recorded on the EKG during the final 15 seconds of the second and third minute of each stage, and during the final 15 seconds of each additional minute that was required to reach steady state heart rate.

The resistance was removed from the ergometer and the subject was told to begin a cool down period. Water was offered to the subject. The subject dismounted the ergometer when the heart rate had reached pre-exercise levels.

The information from the session was inserted into equation 1 (PWC max prediction equation) as listed in the literature review section and calculated.

<u>Elevated Pre-Test Heart Rate Prior to PWC max Test</u>

The following three methods of elevating pre-test heart rate were randomized.

Only the workloads that were used for predicting the maximal working capacity of the subject were used for the following three testing session. This consisted of the first two workloads from the resting condition that elicited heart rates above 110 bpm but were below 150 bpm.

<u>Day 3- Cold Pressor Test Prior PWC max Test</u>

The subject arrived to the laboratory and was instructed to lie on the treatment table for 10 minutes to allow the heart rate to reach the lowest resting level. The EKG electrodes were placed during this time. After the subject had rested for the appropriate time, a 30 second resting heart rate was measured with the EKG. The subject then mounted the cycle ergometer.

The seat height was adjusted and the test was explained again to the subject. An ice bucket containing a 4° C ice and water mixture was placed next to the subject. The subject was instructed to submerge the left arm into the ice mixture for 30 seconds. Heart rate was measured and recorded during the entire 30-seconds that the subject had the arm submerged in the ice mixture using the EKG.

The metronome was turned on and the first workload that elicited a heart rate that was at least 110 bpm during the resting condition was applied. The subject pedaled at this workload until two separate minutes elicited heart rates that did not differ by 5 beats per minute (steady state heart rate). Once steady state heart rate had been reached for the first workload, the second workload that elicited a steady state heart rate greater than 110 beats per minute was applied. The second workload was complete after the subject had pedaled for two consecutive minutes that elicited steady state heart rates. Heart rates were recorded using the EKG during the final 15 seconds of the second and third minute of each stage and any additional minutes that were needed to reach steady state heart rate.

The tension was removed from the ergometer and the subject was told to begin a cool down period. Water was offered to the subject. The subject was allowed to dismount the ergometer after the heart rate had reached pre-exercise levels.

The steady state heart rates obtained from the test were inserted into equation 1 (PWC max prediction equation) as listed in the literature review section and calculated

<u>Day 4 – Exercise Prior to the PWC max Test</u>

The subject arrived to the laboratory and lay on the treatment table for 10-minutes to allow the heart rate to reach it's lowest resting level. The EKG electrodes were placed

during this time. After the subject had rested for the appropriate time, a 15 second resting heart rate was recorded with the EKG. The subject then mounted the treadmill.

The subject straddled the treadmill belt while the treadmill was set at 3 miles per hour and 0% grade. The subject then walked for 3-minutes. If the heart rate did not increase by 10-15 beats, the grade was increased by 1% grade for each minute until the desired heart rate increase was elicited. Heart rate was measured during the final 15 seconds of the treadmill walk. The subject was instructed to take position on the cycle ergometer.

The metronome was turned on and the first workload that elicited a heart rate that was greater than 110 beats per minute during the resting test was applied. The subject pedaled at this workload until two separate minutes elicited heart rates that did not differ by 5 beats per minute (steady state heart rate). Once steady state heart rate had been reached, the second workload that elicited a steady state heart rate greater than 110 beats per minute during the resting test was applied. The second workload was completed after the subject had finished two consecutive minutes that elicited steady state heart rates. Heart rates were recorded with the EKG during the final 15 seconds of the second and third minute of each stage and any additional minutes that were needed to reach steady state heart rate.

The resistance was removed from the ergometer and the subject was told to begin cool down period. Water was offered to the subject. The subject was allowed to dismount the ergometer after the heart rate had reached pre-exercise levels.

The steady state heart rates from the test were inserted into equation 1 (PWC max prediction equation) as listed in the literature review section and calculated

Day 5 – Caffeine Ingestion Prior to the PWC max Test

Two caffeine pills (400 mg total) were distributed to the subject during the initial orientation session. The subject was asked to consume these caffeine pills one hour prior to arriving to the laboratory for the caffeine condition.

The subject arrived to the laboratory and lay on the treatment table for 10-minutes to allow the heart rate to reach the lowest resting level. The EKG electrodes were placed during this time. After the subject had rested for the appropriate time, a 30 second resting heart rate was measured with the EKG. The subject was then asked mount the cycle ergometer.

The seat height was adjusted and the metronome was turned on. The first workload that elicited a heart rate that was greater than 110 beats per minute during the resting test was applied. The subject pedaled at this workload until two separate minutes elicited heart rates that did not differ by 5 beats per minute (steady state heart rate). Once steady state heart rate had been reached, the second workload that elicited a steady state heart rate greater than 110 beats per minute during the resting test was applied. The second workload was completed after the subject had finished two consecutive minutes that elicited steady state heart rates. Heart rates were recorded with the EKG during the final 15 seconds of the second and third minute of each stage and any additional minutes that were needed to reach steady state heart rate.

The resistance was removed from the ergometer and the subject began a cool down period. Water was offered to the subject. The subject was allowed to dismount the ergometer once the heart rate had reached pre-exercise levels.

The test results were inserted into equation 1 (PWC max prediction equation) as listed in the literature review section and were calculated.

Data Analysis

The independent variables were the methods of elevating pre-exercise heart rate: exercise, cold presser and caffeine. The dependent variables were the Steady State Heart Rates obtained from the two workloads and the PWC max value that was calculated from steady state heart rates. The three methods of elevating pre-exercise heart rate were randomized.

Mean Pre-Test Heart Rate (PTHR), SSHR for workload 1 and workload 2, and PWC max were analyzed using a repeated measures ANOVA with the four levels for each variable being rested, cold pressor, exercise, and caffeine for each workload and condition. Post-Hoc testing was completed to discover the source of any significant differences between methods. Microsoft Excel[10] and SPSS[11] statistical software were used to analyze the data collected. Statistical significance was accepted at $p \leq .05$. The study was a one way within subjects design.

[10] Microsoft Corporation, Redmond Washington, USA
[11] SPSS Inc.

CHAPTER 4

RESULTS

For clarity, the completely resting method (criterion method) will be referred to in the figures as REST, and the three experimental methods of elevating pre exercise heart rate will be referred to as EXER (exercise), CF (caffeine), and CP (cold-pressor).

Pre-Test Heart Rate

The goal of the three methods of elevating pre-test heart rate (PTHR) was to raise the heart rate 5-10 beats higher than the resting level prior to the PWC max test. Figure 4 shows that the PTHR for the three treatment conditions was significantly different from the resting condition ($F_{(3,42)} = 61.64$, $p < .0001$). The average PTHR and the change when compared to resting heart rate for the four conditions can be found in table 2.

Table 2: PTHR for Resting Condition and the Three Experimental Conditions With ±SD and Change From Resting Condition.

	Mean PTHR (bpm)	Change From REST (bpm)
REST	57±11	
EXER	79±11	+22
CF	63±10	+6
CP	66±14	+9

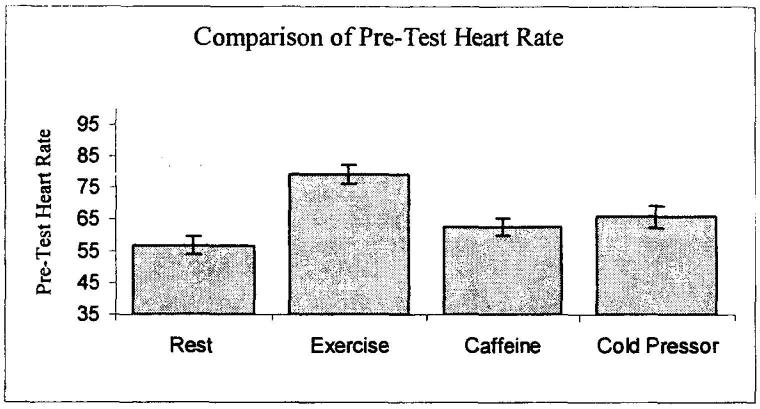


Figure 4: Resting Pre-Test Heart Rate Compared With Three Methods of Elevating Pre-Test Heart Rate. Vertical Bars Indicate ± SD (n=15).

Physical Work Capacity Maximum (PWC max)

There was no significant difference between any of the PWC max values for the 3 methods used to elevate pre-test heart rate when compared to the resting condition ($F_{(3,42)}$= .839, p= .4800). Table 3 lists the means of the PWC max tests for each method and Figure 5 shows that there was no significant difference when comparing resting pre-test heart rates to the three methods of elevating pre-test heart rate.

Table 3: Average PWC max For the Resting Condition and the Three Experimental Conditions With ±SD and Change From Resting Test

	Mean PWX max (kgm)	Change from REST (kgm)
REST	1369±578	
EXER	1359±591	-10±131
CF	1370 ±478	+1±189
CP	1308±486	-61±151

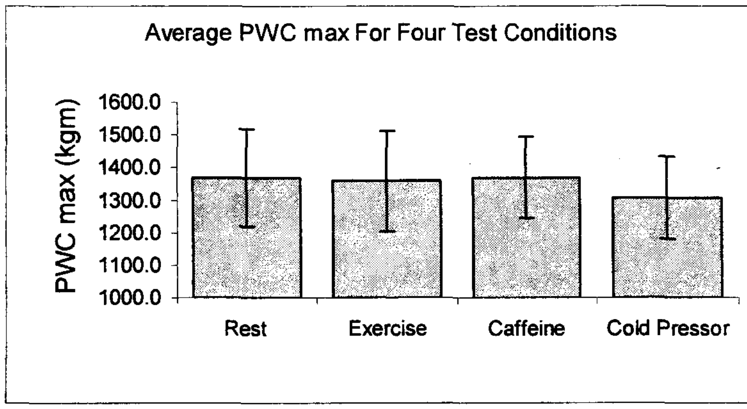


Figure 5: Mean Resting PWC max Compared With Three Methods of Elevating Pre-Test Heart Rate. Vertical Bars Indicate SD ± (n=15).

Steady State Heart Rate and the First Workload

There was a significant difference in the SSHR of the first workloads in the four PWC max tests ($F_{(3,32)} = 2.845$, $p = .0485$) (see Figure 6). Multiple comparison testing revealed that the average SSHR for the resting condition during the first stage was 121 ± 8 beats per minute. Table 4 lists the average SSHR for the resting condition and the experimental conditions and change from the resting condition for the first workload. Post hoc testing showed that the source of the difference was between the REST and CF condition ($p = .0044$) and not between any of the other conditions.

Table 4: Average SSHR for the Resting Condition and the Three Experimental Conditions During the First Workload With ±SD and Change From Resting Test.

	Mean SSHR (bpm)	Change From REST (bpm)
REST	121±8	0
EXER	121±7	0
CF	123±9	+2
CP	122±8	+1

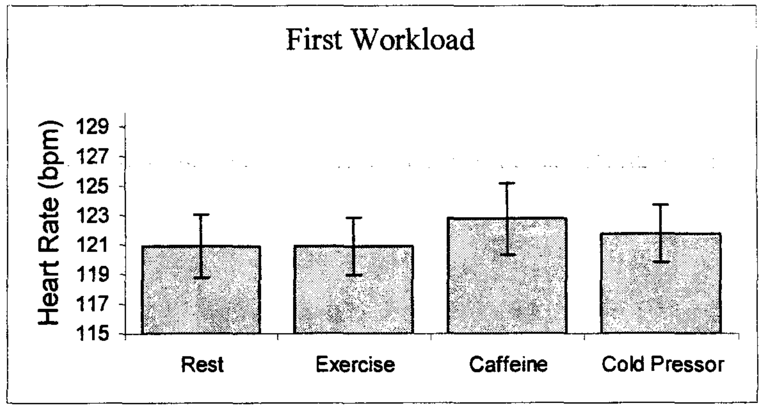


Figure 6: The mean SSHR of the first workload of the PWC max test. Vertical Bars Indicate SD ± (n=15).

Steady State Heart Rate and the Second Workload

There was no significant difference for the SSHR during the second workload that was used to predict PWC max ($F_{(3,32)}$= .967, p= .4171) (see Figure 6). Table 4 lists the average SSHR for the resting condition and the experimental conditions and change from the resting condition for the second workload.

Table 5: Average SSHR For the Resting Condition and the Three Experimental Conditions During the Second Workload With ±SD and change From Resting Test.

	Mean SSHR (bpm)	Change From REST (bpm)
REST	139±14	
EXER	139±13	0
CF	139±12	0
CP	140±12	+1

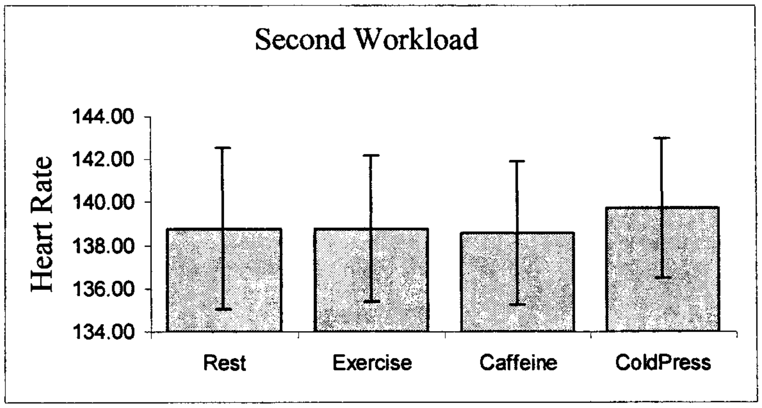


Figure 7: The Mean Resting SSHR of the second workload of the PWC max. Vertical Bars Indicate SD ± (n=15).

CHAPTER 5

DISCUSSION AND CONCLUSION

Discussion

The purpose of this study was to determine whether a slightly elevated pre-test heart rate, elicited by three different methods, affected the results the PWC max test. The results of this study demonstrated that an elevated pre-test heart rate had no significant effect on the results of the PWC max test. A secondary purpose was to see if there was a significant difference in the steady state heart rates (SSHR) of the 2 workloads used in the PWC max prediction. The data showed a significant difference between rest and caffeine during the first workload, but no significant difference for cold pressor or exercise. The SSHR for the second workload showed no significant difference. This chapter discusses possible explanations for the results.

A review of literature revealed a lack of published studies that evaluated the effects of an elevated pre-test heart rate on sub-maximal testing, so comparing the present studies results with other studies is impossible.

Assurances were made that subjects received the same, detailed instructions for performing each of the four sub-maximal tests. They followed all of the pre-test instructions for each testing session, namely: fasting for 6 hours, having not consumed alcohol or caffeine containing beverages or food for 24 hours, having not exercised for 12 hours and having had at least eight hours of sleep the night before the test. Subjects

verbally confirmed that they had followed the instructions prior to each testing session. Subjects also completed a 10-minute resting period prior to testing to assure that the heart rate had reached its lowest level.

Possible errors in heart rate measurement, the workload settings, and the pedal rate were carefully monitored to reduce variability. The heart rates were recorded using a single lead EKG during the final 15 seconds of each workload, and were manually counted. In addition, heart rates were recorded with a Polar heart rate monitor and recorded during the last 15 seconds of each workload to confirm the heart rates. If there was any recognized error in the collection of heart rate, the test was immediately stopped an additional trial was re-scheduled. The workload was constantly monitored and adjusted throughout each PWC max test.

A limitation of this study was that it only evaluated the effects of three methods of elevating pre-test heart rate. There are other conditions that might elevate the pre-test heart rate and this study does not infer that these other conditions will not cause a difference in the PWC max test. The three methods that were used in this study empirically seem like the most logical and common reasons that a subject would arrive for a testing session with an elevated pre-test heart rate.

The Pre –Test Heart Rate (PTHR) was an important value in this study. If the pre-test heart rate was not significantly different in the three testing conditions, the study would have held no value. Since the PTHR was significantly different in all three testing conditions, the results of this study can be considered valid and important.

The PWC max calculation uses two steady state heart rates from two separate workloads to calculate an individuals predicted maximum in kilogram-meters. It is

reasonable that since there was no significant difference between individual steady state heart rates in any of the first workloads used except for the caffeine condition and no significant difference in the second workload that there was no significant difference in the PWC max values.

The lack of a significant difference in PWC max and SSHR values between the resting condition and the three testing conditions as demonstrated may be a reflection that the heart rate will increase to meet the demands that are put on it, no matter what the pre-test heart rate is. Even though the heart rate is elevated above a resting level, it appears that this elevation may not have any effect on the amount of work the heart has to do to maintain a certain workload. Based on the study's results, the null hypothesis is accepted. However, note that the study did show that caffeine ingestion caused an increase in steady state heart rates during low workloads, although there was no significant difference when the PWC max values were compared. The SSHR for the first workload for the caffeine condition did show a significant difference.

Conclusion

Elevating pre-test heart rates by exercise, stress or caffeine in an effort to determine whether an elevated heart rate prior to sub-maximal cardiorespiratory testing effects the tests results was the purpose of this study. The results showed that there was no significant difference in the PWC max test when the pre-test heart rate was slightly elevated. The null hypothesis was retained, stating that an elevated pre-test heart rate does not significantly affect the results of the PWC max test. This fact should be valuable for any one administering a physical fitness test battery that includes

cardiorespiratory testing. The suggestion is that if a subject arrives to the laboratory with an elevated heart rate due to hurrying or previous sub-maximal exercise the results of the PWC max test will be accurate. These results mean that researchers using physical fitness tests no longer need to worry about subject's activities prior to testing. However, due to other pre-test conditions, it should not be recommended that test administrators completely disregard requesting that subjects follow certain guidelines prior to testing. The administrator can, however, know that the results of the PWC max test are not affected by a slightly elevated heart rate caused by exercise, caffeine, or apprehension.

Recommendations For Further Research

1. Future repeated testing of other sub-maximal cardiorespiratory tests such as the 3-minute step test would determine if an elevated pre-test heart affects their results.
2. The current study only evaluated the effects of small changes in pre-exercise heart rate (5-10 beats per minute). Further research is needed to determine the effects of larger changes in PTHR on the results of sub-maximal cardiorespiratory fitness.
3. The current study only evaluated subjects between the ages of 18-33. Since many sub-maximal cardiorespiratory tests are performed on older subjects, the study should be repeated to determine if the same relationship exists in other age groups.
4. Use of an electrically braked cycle ergometer could more accurately maintain workloads during testing sessions.

APPENDIX A

SUBJECT DATA

Appendix A1: Physical Characteristics of Subjects

Subject	Gender	Height (cm)	Weight (Kg)	Age	Abdominal (mm)	Triceps (mm)	Ilium (mm)	Thigh (mm)	Sum4 (mm)	% Body fat
1	F	164	58.4	24	13.5	14.5	23.5	19	70.5	20.9
2	F	164.3	69.1	18	31	24	46	34	135	34.2
3	F	177	63.9	28	19	13	30	12	74	21.8
4	F	167	61.4	27	12	15	32	23	82	23.6
5	F	164	59.7	29	13	14	18	18	63	19.3
6	F	154	57.7	20	24	22	33	26	105	28.4
7	F	158.5	61.8	21	28	26	32	26	112	29.9
8	F	162.5	50.2	22	12	21	23	31	87	24.6
9	F	159.5	58.2	33	31	25	32	30	118	31.4
Mean Females	F	163.42	60.04	24.7	20.39	19.39	29.94	24.33	94.06	26.01
SD Females	F	6.4	5.13	4.9	8.22	5.23	8	7.05	24.52	5.17
10	M	175	72.7	32	8	5	15	8	36	9.3
11	M	172.4	75.5	19	20	15	30	16	81	18
12	M	181.8	81.7	25	35	22	42	21	120	26.6
13	M	175.5	98.2	32	31	27	42	20	120	27.7
14	M	190	79.5	26	21	13.5	21.5	11.5	67.5	16.1
15	M	175.2	78.5	25	12	6	13	10	41	9.5
Mean Males	M	178.32	81.02	26.5	21.17	14.75	27.25	14.42	77.58	17.87
SD Males	M	5.95	8.21	4.5	9.55	7.91	11.75	4.94	33.61	7.3
Mean Total		169.4	68.4	25.4	20.7	17.5	28.9	20.4	87.5	22.8
SD Total		9.8	12.5	4.8	8.8	6.9	9.9	8	30	7.4

APPENDIX B

B1: INFORMED CONSENT

B2: DATA COLLECTION WORKSHEET

B3: HUMAN SUBJECTS APPROVAL

B4: PAR –Q

B5: PWC max PREDICTION SHEET

Appendix B1: Informed Consent

University of Nevada, Las Vegas

Department of Kinesiology

INFORMED CONSENT

TITLE OF STUDY: THE EFFECTS OF AN ELEVATED PRE-TEST HEART RATE ON A CARDIOVASCULAR TEST.

INVESTIGATOR/S: Jeff Dolgan, Lawrence A. Golding, Ph.D.

PROTOCOL NUMBER:

CONTACT INFORMATION:
If you have any questions or concerns about the study, please contact:

Jeff Dolgan	895-2069
Dr. Lawrence A. Golding	895-3766

For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted you may contact the UNLV Office for the Protection of Research Subjects at 895-2794.

Participants:

You are being asked to participate in the study because you are between the ages of 18 and 50 are a routine user of caffeine, are healthy and able to complete sub-maximal exercise without risk and you have completed the PAR-Q. The entire testing session should take less than 1 hour on five separate days (a total of 5 hours). Caffeine ingestion is a requirement of this study. You must also classify yourself as a caffeine user (someone who has used caffeine in the past or uses caffeine on a regular basis). You may choose to refuse ingesting caffeine with no prejudice, however refusal will exclude you from participating in this study.

Procedure:

If you volunteer to participate in the study, you will be asked to commit 5 total hours of your time. In addition to an orientation day, there will be four separate testing sessions in which you will complete a sub-maximal cardiovascular test on a cycle ergometer. This test is called the predicted working capacity maximum test and allows us to predict a person's maximal working capacity and maximum oxygen uptake. This is a sub-maximal test meaning you will be exercising at levels that are below your maximum heart rate (110-150 beats per minute). Maximal heart rate is usually predicted with the equation 220-age. You will be riding the stationary cycle for three to four 3-minute stages

for a total of 9-16 minutes per testing session. All testing will be conducted in the Exercise Physiology Laboratory in the Mcdermott Physical Education (MPE) Center building, room 326.

If you choose to volunteer for this study you will be scheduled for an orientation day and given a time to report to the laboratory. Upon reporting to the laboratory, you will be asked to complete a risk assessment tool called the physical activity readiness questionnaire (PAR-Q). The PAR-Q is designed to identify if physical activity might be inappropriate for an individual or if an individual might need medical advice prior to engaging in physical activity. In addition, resting blood pressure will be measured after you have been sitting for approximately 5 minutes. If you answer yes to any of the questions on the PAR-Q or if your resting blood pressure is slightly elevated (>140/90), you will be excluded from participation in the study. You should answer the questions on the PAR-Q as honestly as possible because it is designed to assure your safety with physical fitness participation.

If you meet the inclusion criteria, and agree to volunteer for the study, specific measurements will be recorded (e.g., height, weight, and body composition). Body composition (the amount of different tissues that make up your body) will be measured by pinching several sites of excess skin on your body by using an instrument that is called a skinfold caliper. The body composition measurement may be slightly uncomfortable, but it should not hurt at all. Depending on how sensitive your skin is you may experience slight bruising. You will also be asked to follow several instructions for the four ensuing testing sessions. These instructions include the following:

1. Do not eat for 6 hours prior to arriving for your appointment.
2. Do not consume alcohol or caffeine containing beverages for 48 hours prior to arriving for your testing session.
3. Arrive to the laboratory well relaxed and rested, after getting a good night of sleep (approximately 8 hours)
4. Arrive at least 20 minutes prior to testing so that heart rate and blood pressure are allowed to reach the lowest resting level.

During the experimental sessions, you will be asked to arrive to the laboratory and begin a 15-20 minute resting period. During this time, three electrodes from a single lead electrocardiogram will be attached to your upper body. If excess hair removal is necessary for electrode placement, it will be removed using a sterile razor and shaving cream.

The experimental sessions will consist of you completing four separate sub-maximal tests on a stationary cycle ergometer. You will be given a separate treatment prior to the start of each of the four testing sessions. These four treatments include the following:

3. The first condition will consist of a completely rested state. When you arrive to the laboratory you will be asked to lie quietly for 15 minutes after which you will complete the PWC max test.

4. The second condition will consist of a cold presser test. The cold presser test is a test in which your left arm will be plunged into a bucket of 4 degree Celsius (39.2 degrees Fahrenheit) ice water for 30 seconds. After this is done, you will be asked to complete the PWC max test.
5. The third condition will consist treadmill walking. The walk will consist of the treadmill being set to 3 miles per hour. If your heart rate has not increased 10-15 beats per minute in 3 minutes, the grade will be increased by 1% for every minute you are on the treadmill. The goal is to raise your heart rate by 10-15 beats per minute. You can expect to be on the treadmill for 3-7 minutes. Once your heart rate has been raised to the desired level, you will be asked to immediately move to the bike and complete the PWC max test. Overall, the test should be considered submaximal effort and will mimic a brisk walk across campus.
6. The final condition will consist of you consuming two 200 mg caffeine pills one hour prior to arriving to the laboratory. This amount of caffeine is approximately equivalent to the caffeine in 2 cups of regular drip brewed coffee. Caffeine ingestion is required for participation in the study and you are free to refuse this treatment without prejudice or penalty. You will complete the 15-20 minutes of rest and will then be asked to move to the bike to complete the PWC max test.

Risks:

Whenever physically stressing adults, there are risks involved. These include musculo-skeletal, or cardiovascular injuries. More specifically, these may include delayed onset muscle soreness, tripping or falling, abrasions, bruising or ecchymosis, extreme fatigue, fainting, breathlessness, psychological stress, nose bleeding, dehydration, irregularities in heart beat, and in rare instances even death. However, all of the physical exercise that will be used during this experiment is well below maximum levels and the risk for these injuries are minimal. The sub-maximal cycle ergometry test has been used in the exercise physiology laboratory for over 28 years without incidence. Regular use of caffeine has been associated with causing high blood pressure. However, in this study you will be asked to take a moderate (i.e., 2 cups of coffee) dosage of caffeine. You may experience some mild symptoms when refraining from your regular caffeine intake. Please communicate any discomfort to us.

Benefits of Participation:

By participating you will be contributing to the body of exercise testing and exercise physiology literature. The anticipated benefit is a better understanding of how an elevated pre-exercise heart rate may affect the reliability of sub-maximal cardiovascular testing. This will help to determine how important it is for subjects to follow the instructions that are meant to eliminate other factors that may affect the test. In additions, you will have the benefit of receiving your body composition and aerobic fitness level calculated and interpreted. Your data are an important part of the investigation and we hope you will receive satisfaction from participating in a research project.

Participation:

Your participation in this study is voluntary. You may refuse to participate in this study or in any part of this study and you may withdraw at any time without prejudice to your relations with the University. You are encouraged to ask questions about this study prior to the beginning or at any time during the study. You will be given a copy of this form.

Cost /Compensation:

There will be no financial cost to you to participate in this study. You will not be compensated for your time. The University of Nevada, Las Vegas may not provide compensation or free medical care for an unanticipated injury sustained as a result of participating in this research study.

Confidentiality:

All information gathered in this study will be kept completely confidential. No reference will be made in written or oral materials, which could link you to this study. All records will be stored in a locked facility at UNLV for 3 years after completion of the study and destroyed thereafter.

Consent:

I have read and understood the above information and agree to participate in this study. I understand that I may be excluded from the subject pool based on my risk-assessment and resting blood pressure measurement.

Signature of Participant Date

Signature of Researcher Date JAD LAG

Principal Investigator:
Lawrence A. Golding

Appendix B2: Data Collection Worksheet

University of Nevada Las Vegas – Exercise Physiology Laboratory
THE EFFECTS OF AN ELEVATED PRE-TEST HEART
RATE ON A CARDIOVASCULAR TEST

Subject ______________ Phone #_________ E-Mail_________

Orientation Day

1. Birthday________ Age____ 5. M F
2. Informed Consent Signed? Yes No 6. Height_____ cm
3. Resting Blood Pressure ___/___ mmHg 7. Weight______ Kg
4. Resting Heart Rate _____beats per minute.

Body Composition

1. Abdomen______ 2. Iliac Crest________ 3. Triceps________ 4. Thigh_______
Sum of 4______ % Body Fat _______

Males: Percent Fat= $.29669\ (\Sigma 4) - .0005\ (\Sigma 4^2) + .15845\ (AGE) - 5.76377$

Females: Percent Fat= $.29669\ (\Sigma 4) - .00043\ (\Sigma 4^2) + .02963\ (AGE) + 1.4072$

Instructions Given? Y N

PWC max= $\frac{(220\text{-age})\text{-HR2 } [(\text{HR2-HR1})/(\text{WL2-WL1}) \text{ *WL2})}{(\text{HR1-HR2/WL2-WL1})}$

Testing Session 1

Seat Height ______ Method Used REST PEHR____

Stage	Workload	Minute 2 HR	Minute 3 HR	Minute 4 HR
1	150 KGM			
2				
3				
4				

PWC max________

Testing Session 2

Seat Height ______ Method Used__________ PEHR____

Stage	Workload	Minute 2 HR	Minute 3 HR	Minute 4 HR
1				
2				

PWC max________

Testing Session 3

Seat Height ______ Method Used__________ PEHR____

Stage	Workload	Minute 2 HR	Minute 3 HR	Minute 4 HR
1				
2				

PWC max________

Testing Session 4

Seat Height ______ Method Used__________ PEHR_____

Stage	Workload	Minute 2 HR	Minute 3 HR	Minute 4 HR
1				
2				

PWC max________

Appendix B3: Human Subjects Approval

Biomedical IRB - Full Board Review
Approval Notice

DATE: December 10, 2004

TO: Dr. Lawrence Golding
Kinesiology Department

FROM: Office for the Protection of Research Subjects

Notification of IRB Action by Dr. John Mercer
Chair, UNLV Biomedical Sciences Institutional Review Board

RE: Status of Human Subject Protocol Entitled: The Effects of an Elevated Pre-Exercise Heart Rate on Sub-Maximal Cardiovascular
Testing OPRS# 0409 - 1348

This memorandum is notification that the UNLV Biomedical Sciences Institutional Review Board reviewed and approved the subject protocol. Research on the project may proceed once you receive a hardcopy of this memo from OPRS. This approval is effective from December 10, 2004, the date of IRB approval, through December 9, 2005 a period of one year from the initial IRB review.

Should the use of human subjects described in this protocol continue beyond December 9, 2005, it will be necessary for you to request an extension and undergo continuing review. Should you initiate any changes to the protocol, it will be necessary to request additional approval for such change(s) in writing through the Office for the Protection of Research Subjects.

If you have questions or require any assistance, please contact the Office for the Protection of Research Subjects at OPRSHumanSubjects@ccmail.nevada.edu or call 895-2794.

Office for the Protection of Research Subjects (OPRS)
4505 Maryland Parkway Box 451037
Las Vegas, NV 89154-1037
Office (702) 895-2794 Fax (702) 895-0805

Research Administration Building 103 M/S 1037
OPRSHumanSubjects@ccmail.nevada.edu
Website: http://www.unlv.edu/Research/OPRS/

Appendix B4: Par-Q

UNLV

Appendix B4 : Par-Q UNIVERSITY OF NEVADA LAS VEGAS

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)
A Self-administered Questionnaire for Adults

PARTICIPANT IDENTIFICATION

PAR-Q & YOU

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check the ❑ YES or NO opposite the question if it applies to you.

YES NO

❑ ❑ 1. Has your doctor ever said you have heart trouble?

❑ ❑ 2. Do you frequently have pains in your heart and chest?

❑ ❑ 3. Do you often feel faint or have spells of severe dizziness?

❑ ❑ 4. Has a doctor ever said your blood pressure was too high?

❑ ❑ 5. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?

❑ ❑ 6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?

❑ ❑ 7. Are you over age 65 and not accustomed to vigorous exercise?

IF YOU ANSWERED

YES to one or more questions

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness test. Tell him what questions you answered YES on PAR-Q, or show him your copy.

programs

After medical evaluation, seek advice from your physician as to your suitability for:

- unrestricted physical activity, probably on a gradually increasing basis.
- restricted or supervised activity to meet your specific needs, at least on an initial basis. Check in your community for special programs or services.

NO to all questions

If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:

- A GRADUATED EXERCISE PROGRAM- A gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort.
- AN EXERCISE TEST- Simple tests of fitness (such as the Canadian Home Fitness Test) or more complex types may be undertaken if you so desire.

postpone

If you have a temporary minor illness, such as a common cold.

Figure 3.2 The Physical Activity Readiness Questionnaire (PAR-Q) is useful in health fair or mass testing situations for screening out individuals at risk for cardiovascular or metabolic disease.

Appendix B5: Prediction Graph for PWC max Test.

MAXIMUM PHYSICAL WORKING CAPACITY PREDICTION

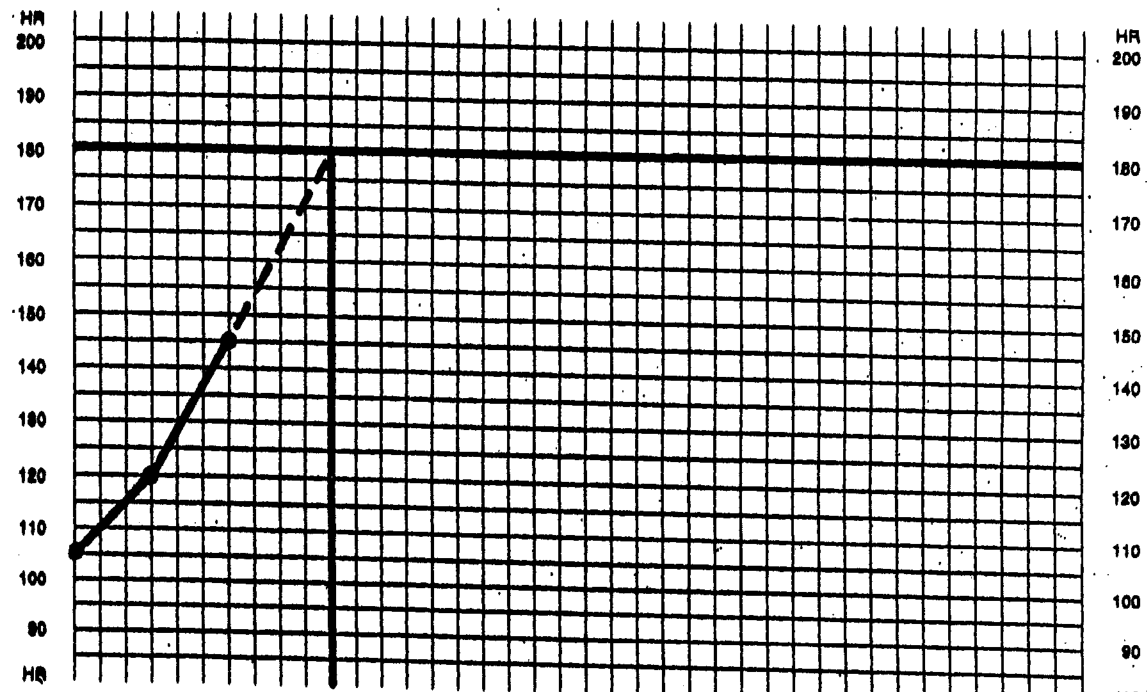
NAME Example Male AGE 40 WEIGHT 176 LB 80 KG SEAT HEIGHT 8

PREDICTED MAX HR 180

	DATE	1st WORKLOAD HR USED	2nd WORKLOAD HR USED	3rd WORKLOAD HR USED	MAX WORKLOAD	MAX O_2(L/min)	MAX O_2(mL/kg)
TEST 1	1-6-00	300/120	450/145	450/145	650	1.6	1600/80 = 20
TEST 2							
TEST 3							

DIRECTIONS

1. Plot the HR of the 2 workloads versus the work (kgm/min).
2. Determine the subject's max HR line by subtracting subject's age from 220 and draw a line across the graph at this value.
3. Draw a line through both points and extend to the max HR line for age.
4. Drop a line from this point to the baseline and read the predicted max workload and O_2 uptake.



WORKLOAD (kgm/min)	150	300	450	600	750	900	1050	1200	1350	1500	1650	1800	1950	2100
MAX O_2 UPTAKE (L/m)	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.8	3.2	3.5	3.8	4.2	4.6	5.0
KCAL USED (kcal/m)	3.0	4.5	6.0	7.5	9.0	10.5	12.0	14.0	16.0	17.5	19.0	21.0	23.0	25.0
APPROX MET LEVEL (for 132 lb)	3.3	4.7	6.0	7.3	8.7	10.0	11.3	12.7	14.0	15.3	16.7	18.0	19.3	20.7
APPROX MET LEVEL (for 176 lb)	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0

APPENDIX C

RAW DATA

C1: RESTING BLOOD PRESSURE

C2: PRE-TEST HEART RATE

C3: STEADY STATE HEART RATE FOR TWO WORKLOADS

C4: PHYSICAL WORKING CAPACITY MAXIMUM

Appendix C1: Resting Blood Pressure Measurement

Systolic/Diastolic Blood Pressure (mmHg)

Subject	Resting Blood Pressure (mmHg)
1	100/70
2	100/72
3	104/68
4	124/90
5	100/70
6	118/80
7	122/70
8	104/60
9	120/90
10	120/78
11	120/90
12	120/74
13	122/80
14	120/90
15	118/80
Average	114/77
SD	±9/9

Appendix C2: Pre Test Heart Rate (bpm) During Four Conditions

Subject	Rest	Exercise	Change	Caffeine	Change	Cold Pressor	Change
1	55	80	+25	60	+5	75	+20
2	68	90	+22	73	+5	92	+24
3	58	92	+34	64	+6	65	+7
4	65	85	+20	70	+5	69	+4
5	47	71	+24	52	+5	62	+15
6	61	84	+23	64	+3	73	+12
7	44	68	+24	50	+6	45	+1
8	56	85	+29	59	+3	56	+0
9	54	80	+26	64	+10	60	+6
10	54	72	+18	68	+14	68	+14
11	70	80	+10	74	+4	75	+5
12	46	70	+24	55	+9	52	+6
13	80	104	+24	84	+4	89	+9
14	42	63	+21	46	+4	48	+6
15	52	65	+13	57	+5	59	+7
Mean	57	79	+22	63	+6	66	+9
SD	±10	±11	±6	±10	±3	±14	±7

Appendix C3: Steady State Heart Rate Used For PWC max Prediction

First Workload

Subject N=15	Rest WL1	Exercise WL1	Caffeine WL1	Cold Pressor WL1
1	128	128	132	128
2	122	121	122	122
3	118	121	118	117
4	131	127	131	132
5	121	118	120	122
6	124	122	127	128
7	112	110	112	112
8	138	137	143	137
9	112	112	116	119
10	120	121	124	120
11	118	120	119	122
12	112	112	112	114
13	132	132	136	128
14	114	117	118	114
15	112	116	112	112
Mean	121	121	123	122
SD	±8	±7	±9	±8

Second Workload

Subject N=15	Rest WL2	Exercise WL2	Caffeine WL2	Cold Pressor WL2
1	154	152	152	152
2	140	140	140	140
3	140	140	138	142
4	160	156	155	156
5	129	126	129	130
6	148	142	142	148
7	124	128	124	127
8	165	163	160	162
9	126	129	127	132
10	144	144	144	144
11	140	141	142	141
12	120	120	124	126
13	148	152	154	150
14	124	125	126	126
15	120	124	122	120
Mean	139	139	139	140
SD	±15	±13	±13	±13

Appendix C4: Predicted Work Capacity (kgm) Maximum From Four Methods

Subject	Rest	Exercise	Change	Caffeine	Change	Cold Pressor	Change
1	1688	1342	-346	1688	0	1470	-218
2	1296	1147	-149	1473	+177	1281	-15
3	1041	923	-118	942	-99	907	-134
4	2306	2231	-75	1995	-311	2306	0
5	1150	1129	-21	1150	0	1150	0
6	2475	2475	0	2000	-475	1975	-500
7	869	880	+11	923	+54	869	0
8	995	1007	+12	965	-30	1050	+55
9	794	813	+19	953	+159	828	+34
10	817	838	+21	894	+77	888	+71
11	992	1025	+33	1080	+88	1025	+33
12	1939	1988	+49	1800	-139	1913	-26
13	1173	1239	+66	1230	+57	1110	-63
14	881	983	+102	1110	+229	938	+57
15	2115	2362	+247	2344	+229	1913	-202
Mean	1368.7	1358.8	-9.93	1369.8	1.06	1308.2	-60.53
SD	±578.7	±590.8	±131.14	±478.1	±188.62	±486.1	±151.12

APPENDIX D

STATISTICAL TREATMENT

E1: DIFFERENCES IN PRE-TEST HEART RATE

E2: DIFFERENCES IN PHYSICAL WORKING CAPACITY MAXIMUM

E3: DIFFERENCES IN STEADY STATE HEART RATE FOR FIRST WORKLOAD

E4: DIFFERENCES IN STEADY STATE HEART RATE FOR SECOND WORKLOAD

Appendix E1: Differences in Pre-Test Heart Rate

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source	Type III Sum of Squares	df	Mean Square	F	P-value	Observed Power[a]
LEVEL	4075.250	3	1358.417	**61.646**	**.0000**	1.000
Error(LEVEL)	925.500	42	22.036			

a. Computed using alpha = .05

Pairwise Comparisons

Measure: MEASURE_1

(I) LEVEL	(J) LEVEL	Mean Difference (I-J)	Std. Error	p-value[a]
Rest	Exercise	-22.467	1.508	< .0001
	Caffeine	-5.867	.768	< .0001
	Cold	-9.067	1.742	.0001
Exercise	Caffeine	16.600	1.707	< .0001
	Cold	13.400	2.334	.0001
Caffeine	Cold	-3.200	1.837	.1034

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Estimates

Measure: MEASURE_1

LEVEL	Mean	Std. Error
1	56.800	2.728
2	79.267	2.912
3	62.667	2.620
4	65.867	3.513

Appendix E2: Differences in Predicted Work Capacity Maximum

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Observed Power[a]
LEVEL	38400.050	3	12800.017	.839	.4800	.216
Error(LEVEL)	640490.200	42	15249.767			

a. Computed using alpha = .05

Estimates

Measure: MEASURE_1

LEVEL	Mean	Std. Error
1	1368.733	149.430
2	1358.800	152.533
3	1369.800	123.443
4	1308.200	125.508

Appendix E3: Differences in Steady State Heart Rate For First Workload

Within-Subjects Factors

Measure: MEASURE_1

WORK1	Dependent Variable
1	REST1
2	EXERCIS1
3	CAFF1
4	COLD1

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Observed Power[a]
WORK1	35.517	3	11.839	**2.854**	**.0485**	.642
Error(WORK1)	174.233	42	4.148			

a. Computed using alpha = .05

Estimates

Measure: MEASURE_1

WORK1	Mean	Std. Error
1	120.933	2.139
2	120.933	1.948
3	122.800	2.409
4	121.800	1.950

Pairwise Comparisons

Measure: MEASURE_1

(I) WORK1	(J) WORK1	Mean Difference (I-J)	Sig.[a]
Rest	Exercise	.000	1.0000
	Caffeine	-1.867	**.0044**
	Cold	-.867	.2155
Exercise	Caffeine	-1.867	**.0258**
	Cold	-.867	.3724
Caffeine	Cold	1.000	.2740

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Appendix E4: Differences in Steady State Heart Rate for Second Workload

Within-Subjects Factors

Measure: MEASURE_1

WORK2	Dependent Variable
1	REST2
2	EXERCIS2
3	CAFF2
4	COLD2

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source	Type III Sum of Squares	df	Mean Square	F	p-value
WORK2	11.650	3	3.883	**.967**	**.4171**
Error(WORK2)	168.600	42	4.014		

a. Computed using alpha = .05

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