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The effects of caffeine ingestion on power output during intermittent high intensity leg ergometry exercise

John C. Ashworth
San Jose State University

THE EFFECTS OF CAFFEINE INGESTION ON POWER OUTPUT DURING INTERMITTENT HIGH INTENSITY LEG ERGOMETRY EXERCISE

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APPROVED FOR THE DEPARTMENT OF HUMAN PERFORMANCE

Carol L. Christensen

Dr. Carol Christensen

Barbara J. Conry

Dr. Barbara Conry

V G Payne

Dr. Greg Payne

APPROVED FOR THE UNIVERSITY

Serena W. Stanford

ABSTRACT

THE EFFECTS OF CAFFEINE INGESTION ON POWER OUTPUT DURING INTERMITTENT HIGH INTENSITY LEG ERGOMETRY EXERCISE

by John C. Ashworth

The purpose of this study was to measure the effects of caffeine ingestion on power output during short term, high intensity exercise. Data was collected and analyzed on 19 male highly trained cyclists aged 20 - 40 yr. A double blind protocol was used and each subject served as their own control, performing two sprint tests on separate days after ingesting either caffeine (5mg/kg of body weight) or a placebo prior to testing. Mean power output expressed in watts/kg was obtained for each 2-min work interval during the sprint tests. Two-way analysis of variance comparing mean power output for the 2nd through 7th work intervals of the two sprint tests indicated no significant differences in mean power output (p=0.18). In conclusion, caffeine in the amount of 5mg/kg of body weight did not significantly effect power output during the intermittent sprint test.

I dedicate this project to my wife Laura. Thank you for all of your love and support throughout this process.

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Chapter I

Introduction

Two of the most important characteristics for athletic success include one's genetic endowment and state of training. Obviously there is no possibility for the manipulation of a person's genes; however, one's training can vary based on the type of sport, time available for training, facilities available, budget, and the motivational level of the athlete. Despite these factors, at high levels of competition, where hundredths of a second can determine who wins a gold medal from a fourth place finish, athletes are fairly equal in their genetic endowement and have been exposed to similar types of training protocols. These facts lead many athletes to extraneous means of achieving their lifelong goal of athletic success. Two of the key factors leading to improved athletic performance in recent years are improved diet and ergogenic aids (Williams, 1992).

Caffeine has been hypothesized to have ergogenic potential for certain types of exercise. Many studies (Burglund & Hemmingson, 1982; Cadarette, Levine, Berube, Posner, & Evans, 1983; Costill, Dalsky, & Fink, 1978; Graham & Spriet, 1991; Ivy, Costill, Fink, & Lower, 1979; Sasaki, Maeda, Usui, & Ishiko, 1987) measured the effects of caffeine on prolonged exercise at a moderate intensity and reported benefits. Despite these findings, question and controversy still exists as to caffeine's ergogenic potential during other types of exercise. In extensive literature reviews on this subject, Powers and Dodd (1985), and more recently Dodd, Herb, and Powers (1993) reported no improvements in performance following caffeine ingestion during graded, incremental exercise. In addition, research measuring caffeine's glycogen sparing effect during short term, high intensity exercise is limited.

In most investigations measuring the effects of caffeine on prolonged, moderate intensity exercise, the authors attribute the benefit to caffeine's effect on increasing free fatty acid metabolism and the resulting glycogen sparing. In three different investigations of this type (Butts & Crowell, 1985; Costill, et al., 1978; Ivy, et al., 1979), an increase in the levels of free fatty acids was found during the caffeine trial. The researchers concluded that the increased amount of work, or time to fatigue, was a direct result of the glycogen sparing effect of caffeine. By enhancing the levels of free fatty acids in the blood stream, caffeine promotes fat metabolism and spares muscle glycogen to be used later in exercise. This usually leads to an increased amount of work performed and an increased time to fatigue.

Statement of the Problem

Research regarding short term, high intensity exercise is sparce and unclear. According to Dodd, et al. (1993), the majority of research on animals has consistently shown caffeine to enhance muscle force production, while human studies continue to show no benefits of caffeine during short term, high intensity exercise. The problem in examining the effects of caffeine on short term, high intensity exercise is threefold. First, with animal studies, very high doses of caffeine are administered, making generalization to humans impossible. Second, this research (Bond, Gresham, McRae, & Tearney, 1986; Williams, Signorile, Barnes, & Henrich, 1988) has focused on caffeine's effect on isolated muscle, specifically caffeine's enhancement of calcium release and its effect on isolated muscular contractions. Lastly, studies examining caffeine's effect on performance (Anselme, Collomp, Ahmaidi, & Prefaut, 1992; Collomp, Ahmaidi, Audran, Chanal, & Prefaut, 1991; Collomp, Ahmaidi, Chatard, Audran, & Prefaut, 1992), have used testing protocols that were not long enough to measure caffeine's glycogen sparing effect. Also, these testing protocols did not warrant generalization to any specific athletic setting.

During short term, high intensity exercise the main source of energy is carbohydrates, and the main cause of fatigue in exercise is carbohydrate depletion (McArdle, Katch, & Katch, 1991). The purpose of this investigation was to examine the effects of caffeine on repeated bouts of short term, high intensity exercise where the glycogen sparing effect of caffeine may play a vital role.

Significance of the Problem

Knowing the effects of caffeine on repeated bouts of short term, high intensity exercise is valuable information for athletes involved in this type of activity. Sports such as basketball, soccer, and tennis require numerous short bursts of energy throughout any game. If ingesting caffeine has a positive influence on power output as exercise continues, these athletes could benefit from ingesting caffeine before competition.

Null Hypothesis

There are no significant differences in mean power output during trials two through seven of a sprint test after ingesting either caffeine (5mg/kg body weight) or placebo.

Delimitations

This study was limited to male, competitive cyclists who averaged 100 mi/week, or more, cycling for a period of one year prior to the start of this investigation.

Limitations

Limitations inherent in this investigation include the following.

1. Subjects may not have exerted a maximal effort during the sprint tests.
2. A non-random sample was used which limits the generalizability of the results to those individuals who match the characteristics of the subjects used during this investigation.
3. The experiment was conducted in the laboratory setting. The laboratory setting is much different than the normal riding conditions of the subjects. This factor could have affected their performance.
4. Individuals' sensitivity to caffeine varies, making their results difficult to compare.
5. There was no way to confirm each subject's abstinence from caffeine prior to and during the study period.

Operational Definitions

Ergogenic aid--any substance or means that is designed and/or used to enhance physical performance (McArdle et al., 1991).

Sprint test--a series of eight maximal sprints on the cycle ergometer, each lasting two minutes, and each separated by one minute of rest.

Power output--measured in watts, this is defined as the amount of work performed and calculated using the following formula: P = *Revolutions per minute X Kilopounds(level of resistance) x 6m(distance traveled with each rpm).*

Sprint workload--the amount of resistance set on the cycle ergometer; calculated for each subject at *.045kg per kg of bodyweight.*

Summary

Caffeine is implicated as an ergogenic aid (Powers & Dodd, 1985). In prolonged, moderate intensity exercise, caffeine has been shown to increase time to fatigue and the amount of work performed mainly as a result of its glycogen sparing effect (Powers & Dodd, 1985). Caffeine's effect on short term, high intensity exercise is not clear. Research on animals, using large amounts of caffeine and focusing on caffeine's effect on muscle force production, has shown benefits. However, the majority of human studies show more conflicting results (Jacobson & Kulling, 1989). The main problem has been that caffeine's glycogen sparing effect has been analyzed only once during short term, high intensity exercise (Trice & Haymes, 1995). As a result, the purpose of this investigation was to measure the effects of caffeine on power output during a series of repeated bouts of short term, high intensity exercise.

Chapter Two

Review of Literature

Introduction

This chapter is divided into five sections. The introduction is followed by literature reviews on caffeine and exercise; caffeine and endurance exercise; and caffeine and short term, high intensity exercise. These sections are followed by a chapter summary.

The effects of caffeine on exercise have been well documented. More specifically, research has consistently shown beneficial effects of caffeine ingestion on performance during endurance exercise (Dodd et al., 1993; Costill et al., 1978; Ivy et al., 1979). The main reason cited for caffeine's beneficial effects on this type of exercise is its enhancement of fatty acid metabolism and the resulting glycogen sparing effect. However, this effect has not been measured during short term, high intensity exercise where the main source of energy is carbohydrates (Snyder, Moorhead, Luedtke, & Small, 1993). Instead, the research on this type of exercise has focused on the cellular actions of caffeine, specifically, caffeine's influence on calcium release and how this affects muscular contraction and the exertion of force. Therefore, the purpose of this investigation was to measure the effects of caffeine on repeated bouts of short term, high intensity exercise performance in relation to caffeine's glycogen sparing effect.

Caffeine and Exercise: A Review

In an article published in 1989, Jacobson and Kulling review the literature on caffeine's effects on physiological functioning and exercise. The authors state that no beneficial effect occurs for caffeine on exercise performance lasting at least one hour and at an intensity level of between 60-85% of maximal oxygen consumption. All studies reviewed in this article attribute these benefits to caffeine's glycogen sparing effect. The authors also state that at shorter durations and higher intensity levels there are no benefits of caffeine ingestion.

In an extensive review article published in 1993, Dodd et al. described caffeine and its cellular mechanisms of action and its effects on three different types of exercise. Research on short term, high intensity exercise has focused on both animals and humans, and usually examined caffeine's effect on calcium release in the sarcoplasmic reticulum in the muscle. This increased release of calcium could theoretically enhance force production in the muscle and, in turn, improve performance. The problem with research in this area, however, is that the high amount of caffeine needed to produce beneficial effects in animals is not a suitable dose for humans. During graded, incremental exercise, past research also supports no benefits of caffeine. During endurance performance caffeine does show some benefits, mainly an increased time to fatigue. Dodd et al. concluded that the beneficial effects of caffeine on endurance performance are mainly due to caffeine's glycogen sparing effect.

In an earlier review of the literature Slavin and Joenson (1985) outlined the sources of caffeine and caffeine's effects on endurance performance. Based on a limited review of the research, the authors indicated that caffeine's benefits are mainly due to its enhanced stimulation of fat breakdown and the resulting glycogen sparing effect. The research they reviewed examined the effects of caffeine on substrate utilization. Four out of the five studies reviewed reported significant reductions in carbohydrate utilization following caffeine ingestion. Slavin and Joenson concluded that well trained endurance athletes are generally more efficient in their utilization of free fatty acids, resulting in a natural glycogen sparing effect. The effects of caffeine ingestion on these individuals, therefore, may be minimal.

Caffeine and Endurance Exercise

In a review of the literature on caffeine and exercise, Powers and Dodd (1985) focused their search on studies measuring caffeine's effect on endurance performance. In this review they discussed the effects of caffeine on three types of performance: short term, high intensity exercise; graded or incremental exercise; and endurance exercise. The authors concluded that the majority of the research on short term, high intensity exercise suggests no benefits of caffeine ingestion on performance. No conclusions were made regarding the effects of caffeine on graded, incremental exercise due to the existence of varying protocols, a lack of control for caffeine tolerance, and the existence of an equal number of studies to support both benefits and no benefits of caffeine ingestion. Despite these findings this review resulted in considerable evidence that caffeine enhances prolonged submaximal exercise performance as a result of its glycogen sparing effect.

In 1978, Costill et al. examined the effects of caffeine on metabolism and performance during prolonged exercise to exhaustion. Two female and seven male subjects cycled at 80% of their maximal oxygen consumption (VO2max), after ingesting 330mg of caffeine and again after a placebo. Subjects were not informed of the intent of the experiment. Blood samples were drawn and respiratory exchange determined. During the caffeine trial, an increased rate of lipid metabolism and decreased use of carbohydrates was evident. In addition, subjects were able to perform 19.5% more work than during the placebo trial. The authors concluded that the increased work was a result of caffeine's glycogen sparing effect.

In 1985, Butts and Crowell assessed the effects of caffeine on submaximal endurance exercise. After taking measurements of VO2max on 15 active females and 13 active males, each subject performed two cycling tests in a double blind fashion. Each test consisted of ingesting either 300mg of caffeine or a placebo one hour prior to cycling at 70-75% of their VO2max until exhaustion. Exhaustion was either voluntarily determined or defined as the inability to maintain a pedaling frequency of 60 rpm. Respiratory parameters, heart rates, and ratings of perceived exertion were also measured. Results demonstrated a tendency toward an enhanced performance during the caffeine trial for both men and women, but the differences were not significant. No significant differences in performance were reported between the caffeine and placebo trial for either the men or the women. Caffeine appeared to have a similar effect on both men and women.

Ivy et al. (1979) measured the effects of carbohydrate and caffeine ingestion on work production and substrate metabolism. During two hours of isokinetic cycling, seven male and two female trained cyclists performed three different tests in a randomly assigned order. After a practice ride, each subject performed control, glucose polymer, and caffeine trials. During the caffeine trial, 500mg of caffeine were administered; 250 mg were ingested exactly one hour prior to the test and the remaining 250 mg were administered in divided doses given just prior to the test and every 15 minutes during testing. The glucose polymer solution consumed provided approximately 90g of polymer for each subject. Results showed that during the caffeine trial, subjects performed 7.4% more work than during the control condition and 5.3% more work than during the glucose polymer trial. Fat oxidation was also highest during the caffeine trial, and the authors concluded that the increased fat metabolism over the last hour of exercise contributed significantly to the increased amount of work performed during this trial.

Caffeine and Short Term, High Intensity Exercise

In an investigation by Collomp et al. (1992), the purpose was to determine whether specific training is necessary to produce benefits from caffeine ingestion during a swimming test. Fourteen subjects, seven trained and seven untrained, performed two tests. In a double blind fashion, each subject performed two 100 meter swims at maximum speed. Each test was separated by 20 minutes of passive recovery. One test was performed once after ingesting 250 mg of caffeine and the other after ingesting a placebo. Lactate levels were measured periodically during each test. Lactate levels were higher in all fourteen individuals during the caffeine trial. Results indicated that caffeine improved performance for the trained subjects only. The authors concluded that this indicates a necessary and specific training factor in order to improve anaerobic capacity with caffeine.

In a study by Anselme et al. (1992) , a force-velocity test on the cycle ergometer was used to determine the effects of caffeine during short term, high intensity exercise. Each of the 14 subjects, which included 10 men and 4 women, were tested in a random, double blind order after ingesting either 250mg of caffeine or a placebo. Each test consisted of maximal sprints on the cycle ergometer lasting 6 seconds and separated by 5 minute recovery periods. Subjects performed successive tests with increasing loads until the last increase caused a decrease in maximal anaerobic power. Results showed an increase in maximal anaerobic power with caffeine and also an increase in lactate levels at the end of pedaling. The authors concluded that these increases in lactate levels were a direct result of the caffeine.

Williams et al. (1988) attempted to measure caffeine's effect on maximum power output and fatigue during a 15 second sprint test on the cycle ergometer. Nine adult males, known to have a low caffeine intake (less than 70mg per day) participated. A double blind research procedure was employed and subjects were tested exactly one hour after ingesting either caffeine (7mg/kg of body weight) or a placebo. Results clearly showed no improvement in maximum power output or any delay in the onset of fatigue after the ingestion of caffeine. However, the single 15 second test appeared to be the biggest limiting factor in this study. Anselme et al. (1992) and Collomp et al. (1992) were both able to demonstrate benefits from caffeine ingestion by using more than one bout of short term, high intensity exercise.

Bond et al. (1986) investigated the effects of caffeine on maximal voluntary contractions of the dominant extension and flexion muscles of the knee joint in 12 intercollegiate track sprinters. After participating in two practice sessions of the actual test, subjects were tested on two separate days separated by one week. Using a double blind protocol, subjects completed a total of 18 trials at 30, 150, and 300 degrees per second, rested for two minutes, and then performed a series of 60 maximal repetitions at 150 degrees per second on the Cybex machine. From the data collected, measures of peak torque, power, and fatigue were calculated. No significant effects of caffeine were found for isokinetic flexion or extension of the knee during this investigation. The authors concluded, however, that as contraction velocity increased, power increased, though insignificantly, during the caffeine trial.

In another study by Collomp et al. (1991), the authors assessed the effects of caffeine on three males and three females during performance on the Wingate Test. Using only a single blind protocol, the subjects each performed the test twice, once after ingesting caffeine (5mg/kg of body weight) and once after ingesting a placebo. Measurements of anaerobic power and capacity and power decrease were taken for both trials. Anaerobic power was defined as the peak power obtained during any 5 second interval, and was calculated as velocity times resistance. Anaerobic capacity was defined as total work performed over the entire 30 second test and was calculated as, resistance times pedal revolutions times 6. And finally, power decreases were calculated as the difference in peak power and the lowest 5 second power level divided by total time of the test (30 seconds). Subjects abstained from caffeine for 1 week prior to the test and for the remaining 3 days of testing. Results showed no differences between caffeine and placebo trials in anaerobic power, anaerobic capacity, and power decreases. Catecholamine secretions and lactate levels were elevated with caffeine, however. The authors concluded that there is no scientific reason for untrained athletes to use caffeine before supramaximal exercise. However, one 30 second test may not be long enough to take advantage of caffeine's glycogen sparing effect.

In a recent investigation conducted by Trice and Haymes (1995) a double blind protocol was used to measure the effects of caffeine ingestion on exercise-induced changes during high intesity, intermittent exercise. Eight trained male volunteers aged 21-32, who were not regular caffeine users were chosen for the study. Each subject performed two intermittent cycling tests on separate days following ingestion of either caffeine (5mg/kg of body weight) or placebo. The intermittent exercise protocol consisted of 30 minutes of alternating 1 minute cycling and rest periods. Subjects were encouraged to complete three of these 30 minute exercise bouts at 70 rpm. Each bout was separated by 5 minutes. During this test, subjects pedaled 70 rpm at 85-90% of the maximum workload achieved during their VO2max test. The exercise was terminated when the subject failed to complete three 30 minute periods or when the subject failed to maintain 70 rpm for a 15 second period. Each intermittent cycling test was preceeded by a 12 hour fast and 24 hours of abstinence from caffeine. Results showed a significant increase in free fatty acid concentration and time to exhaustion (16.25 min) following the caffeine treatment. This increase in time to exhaustion occurred without any significant increases in heart rate or oxygen uptake during the caffeine trial. The authors concluded that caffeine ingestion in the amount of 5 mg/kg of body weight increased time to fatigue as a result of caffeine's glycogen sparing effect.

Caffeine Naive Versus Habituated Subjects

Dodd, Brooks, Powers, and Tully (1991) measured the effects of caffeine on graded exercise performance in caffeine naive (CN) versus habituated (CH) subjects. It was theorized by the authors that caffeine ingestion might increase VO2max and/or delay the onset of the anaerobic threshold in CN versus CH subjects. Seventeen moderatley trained males were chosen and placed in one of two groups depending on their caffeine consumption. The CN group consisted of those who consumed less than 25mg/kg/day of caffeine and totaled eight subjects. The CH group totaled nine subjects and included those who consumed greater than 300mg/kg/day of caffeine. Subjects were asked to maintain a balanced diet for two days prior to testing and to refrain from any activity or caffeine consumption for 24 hours prior to testing. Subjects, following a 4 hour fast, reported to the laboratory three times within 7 days and performed a VO2max test on each day. One hour before each test, using a double-blind design, the subjects ingested either: (a) a gelatin capsule; (b) caffeine in the amount of 3mg/kg of body weight; or (c) caffeine in the amount of 5mg/kg of body weight. Results indicated no significant differences in ventilation, respiratory exchange ratio, heart rate, or time to exhaustion between groups or between treatments within groups. The authors noted that caffeine had a greater effect on resting heart rate, ventilation, and VO2 in CN subjects and that this may help to explain some of the discrepency regarding the physiological effects of caffeine reported throughout the literature. However, they concluded that the effects of caffeine on exercise performance in CH and CN subjects, evaluated using VO2max and the anaerobic threshold, are not different.

Summary

The research measuring caffeine's potential as an ergogenic aid is extensive (Dodd et al., 1993; Powers & Dodd, 1985). Studies have been performed to measure caffeine's effects on muscular strength and endurance; short term, high intensity exercise; graded, incremental exercise; and on prolonged endurance exercise (Anselme et al., 1992; Bond et al., 1986 ; Collomp et al., 1992; Ivy et al., 1979; Williams et al., 1988). From the literature, caffeine appears to have some beneficial effects on endurance performance as a result of its glycogen sparing effect. Every investigation finding benefits of caffeine ingestion prior to prolonged endurance exercise, attribute the benefits to caffeine's glycogen sparing effect (Costill et al., 1978; Dodd et al., 1993; Ivy et al., 1979; Powers & Dodd, 1985).

Although there is some evidence of caffeine as an ergogenic aid for performance during short term, high intensity exercise, none of the research has focused on caffeine's glycogen sparing effect. The short term energy system depends largely on glycogen stored in the muscles (McArdle et al., 1991) . Therefore, a study of caffeine's glycogen sparing effect on short term, high intensity exercise, where performance relies heavily on carbohydrates, is warranted. This type of investigation is also more practical in terms of being able to generalize the findings to specific athletic situations such as basketball, soccer, and tennis, where repeated bouts of short term, high intensity exercise are inherent.

Chapter III

Methods

Introduction

This chapter explains subject selection, the instrumentation used for measurements, research design and protocol, procedures followed, and statistical techniques.

Subject Selection

A non random method of subject selection was used for this investigation. Twenty highly trained male cyclists, aged 20 - 40 years, were chosen to participate in this investigation. Subjects were recruited by posting flyers on campus bulletin boards at San Jose State University; flyers were also distributed at local cycling races. The majority of subjects, however, were recruited from a posting to the Northern California Cycling Organization mailing list (ncnca@cycling.org) on the internet. For the purposes of this research, a highly trained cyclist was defined as any individual who had averaged 100 miles per week or more during training and competition for a period of one year prior to this investigation. All were currently cycling at a competitive level. All subjects completed a health screening questionnaire (Appendix A) and signed an informed consent form (Appendix B) before participating in the study. Subjects were also given a pre-test instruction sheet (Appendix C) three to seven days prior to testing which included information on all testing procedures. Upon initial contact, all subjects were instructed to refrain from caffeine consumption from that time forward until all testing was completed. Caffeine abstinence prior to the start of testing ranged from three to seven days.

Instrumentation

Heart rate was monitored during VO2max testing using a Nikon-Hoden electrocardiograph. Electrodes were positioned in a modified CM5 configuration. During the sprint tests a Polar, "Favor Model," heart rate monitor was used to measure heart rate. The Medgraphics Metabolic CPX-D Cart was used to measure gas exchange parameters and was calibrated prior to each test. A Monark 818 cycle ergometer was used for all testing and was calibrated prior to the start of testing, and once each week during testing so that set resistances were accurate and reliable.

For each two minute sprint, a measurement of power output was taken using Sports Medicine Industries Power Program, version 1.02, on an IBM computer. The program was set to run for 120 seconds. The computer interfaced with the ergometer via a magnetic sensor running from the computer to the flywheel of the cycle ergometer. This sensor was used to measure revolutions per minute, which the computer program used to calculate mean, maximum, and minimum power.

Lange skinfold calipers were used to take skinfold measurements at the subject's chest, abdomen, and thigh. The Jackson and Pollock (1978) formula was used to calculate body density and the Brozek equation was used to estimate body fat percentage (Brozek, J., Grande, F., Anderson, J., & Keys, A., 1963). A stadiometer was used to measure the height of the subjects in centimeters, and a balance scale was used to take weight measurements in kilograms. All anthropometric measurements were taken prior to each subject's VO2max test.

Procedures

All subjects were tested on three separate occasions. Maximal oxygen consumption tests were administered as incentive for subjects to volunteer for this investigation and to verify each subject's training level. The VO2max test was administered and was followed within one week by two identical sprint tests. Results of the VO2max tests were available to the subjects upon completion of the second sprint test. All three tests, the VO2max test and the two sprint tests, took place within a one week period. This prevented any training effects from occuring and helped familiarize the subjects with the cycle ergometer. Each test, including the VO2max test, was separated by 48-96 hours.

The nature and purpose of this investigation was explained to the subjects verbally and in writing using the informed consent form and pre-test instruction sheet. Informed consent was approved by the San Jose State University Institutional Review Board-Human Subjects.

Diet and Caffeine

All subjects were asked to maintain their normal diets and to abstain from caffeine consumption from the time they were initially contacted until all three tests were completed. Abstaining from caffeine consumption helped to prevent the development of a caffeine tolerance (Collomp et al., 1992) . The time frame of caffeine abstinence prior to the start of testing ranged from three to seven days depending on when a subject was contacted and subsequently scheduled for testing. No subject, however, was tested with less than three days of caffeine abstinence. Subjects were instructed to refrain from caffeine consumption until all testing was completed. Maintaining their normal diets meant that the subjects did not change their normal eating habits for this investigation. Subjects were also asked to refrain from eating for three to four hours prior to each test.

Caffeine was dissolved in 400ml of Crystal Light lemonade in the amount of 5mg/kg of body weight. Subjects not performing the caffeine trial ingested 400ml of the lemonade without the caffeine added. This amount of caffeine corresponds to the amount used in an investigation by Collomp et al. (1992), where the effects of caffeine ingestion during performance on the Wingate test were measured.

VO2max

The VO2max test was a graded exercise test on the cycle ergometer. For the calculation of VO2max, measurements of ventilation and expired gas were taken. Subjects, wearing a nose-clip, inspired room air through a pneumotach which measured ventilation volume. As air was expired, gas samples were drawn off and expired gas, carbon dioxide and oxygen, were measured by the metabolic cart. The measurement of heart rate using the ECG was used as an indicator of overall cardiovascualar work (American College of Sports Medicine [ACSM] , 1991) .

The safety of this test was ensured by adherence to the ACSM guidelines established for all exercise testing. These include the following: " 1) If there is any doubt as to the benefit of testing or the safety of testing, the test will not be performed at that time. 2) The test protocol should be selected to accommodate the individual patient's ability to perform treadmill exercise (walking pace, anticipated exercise capacity) or cycle ergometer exercise. 3) The exercise test should begin at a MET level intensity considerably below the anticipated limitation or maximal capacity and increase gradually in two or three minute stages, with observations made at each different stage. The increase in intensity at each stage may be as large as two to three METs in healthy populations or as small as 1/2 MET in those with disease. 4) Heart rate, blood pressure, rating of perceived exertion (RPE) , and patient appearance and symptoms should be monitored regularly. Grading scales for severity of angina in cardiac patients and dyspnea in pulmonary patients are especially valuable. 5) Contraindications for testing and indications for stopping exercise should be closely observed. 6) All observations should be continued for at least four minutes of recovery unless abnormal responses occur which would require a longer post-test observation. 7) The testing area should be 22 C (72 F) or less, and the humidity of 60% or less if possible" (ACSM, 1991, p. 59-60).

The protocol for the VO2max testing was designed through pilot work and by modifying a formula developed by McArdle, Katch, and Pechar (1973). All anthropometric measurements were taken prior to each subject's VO2max test at a station set-up in the laboratory. After taking anthropometric measurments and applying the electrodes for the ECG, subjects found a comfortable height for the seat on the ergometer and began a warm-up at a self selected cadence and resistance level. Procedures of the test were explained to the subject at this time. All tests were supervised by an ACSM certified exercise specialist and CPR certified individuals.

Subjects were instructed to pedal at a cadence of 80 revolutions per minute for the entire test. The initial resistance level was set for 900 kgm and was increased every minute until voluntary exhaustion. For the first two minutes of testing, the resistance was increased by 300 kgm, and then by 180 kgm for each additional minute of testing until voluntary exhaustion, or until the subject could no longer maintain 80 revolutions per minute. One researcher controlled the resistance while the second researcher monitored the ECG readings and the measurements on the metabolic cart. All subjects were verbally encouraged during each VO2max test to ensure that a maximal effort was obtained. Following an adequate recovery time, subjects performed one 2-minute sprint at the resistance that would be used for the sprint test. This was done to give each subject an idea of how they would need to pace themselves during the sprint test.

Sprint Tests

Within a 1 week time period following the VO2max test, subjects performed the sprint test twice. Each subject served as his own control by performing the sprint test once after caffeine ingestion and once following ingestion of a placebo. A double blind protocol was used so that neither the subject nor the researcher knew which was the caffeine trial. The sprint test consisted of eight 2-minute maximal sprints on the cycle ergometer. Each sprint was separated by one minute of rest in which the subject remained seated on the ergometer and did not pedal. All subjects performed a warm-up on the cycle ergometer of 10 to 15 minutes in duration at a self selected pedal cadence and resistance level (upon completion of pilot work, it was determined that each subject be allowed to select the duration and intensity of the their warm-up in order to ensure a maximal effort during the sprint test).

For the sprint tests, the amount of resistance set on the ergometer for each subject was determined through pilot work; .045kg/kg body weight was used to calculate resistance on the ergometer for each subject. The initial resistance chosen for the pilot work was calculated by modifying the formula used during the Wingate Test to calculate workload (Collomp et al., 1991). During the Wingate Test resistance is set at .075kg per kg of body weight. For the purposes of this investigation, where each sprint performance was four times the length of the Wingate Test, it was theorized that the resistance should be set at .05kg per kilogram of body weight. However, this resistance was too high and did not allow the person being tested to finish all eight trials. Subsequent tests were performed at resistances of .03 and .045kg per kilogram of body weight. Through data collected on all tests it was decided that the resistance of .045kg per kilogram of body weight would be used. This resistance was difficult enough to cause a consistent decrease in power output across eight trials, while allowing the subject to exert a maximal effort throughout the entire test.

The sprint tests were administered by two technicians. A partition was placed between the computer and the ergometer so that the subject had contact with only one individual during the sprint tests, the individual providing the feedback. The computer operator sat quietly and recorded measurements provided by the computer program. The laboratory setting and equipment layout was the same for every subject during all tests. Both sprint tests for each subject took place at approximately the same time of day.

Following a 3 to 4 hour fast, subjects arrived at the laboratory and ingested either caffeine or placebo. Following ingestion, the procedure of the sprint tests and the expectations of the subject were explained by the same individual for all tests. These procedures and instructions were given using an instruction sheet that was read to each subject (Appendix E) . Subjects were instructed to perform as much work as possible (sprint as hard as possible) for each two minute interval. After reading the instructions, the subject was asked how long they would need for a warm-up. Depending on the amount of time needed, the subject started the warm-up soon enough to allow the sprint test to start at exactly one hour post absorption of either caffeine or placebo. The amount of time requested for warm-up ranged from ten to fifteen minutes. At 40 minutes post-absorption, subjects were asked if they needed to use the bathroom if they had not already requested this. Upon returning from the bathroom, the heart rate monitor was attached and subjects were instructed to find a comfortable position on the ergometer and begin their warm-up. The goal of the warm-up was to prepare the subject for a maximal effort. Therefore, the subjects were given the freedom to control the duration and intensity of the warm-up.

At 55 minutes post-absorption, a brief set of instructions was read to the subject by the individual providing all other instructions; the subject was also instructed that there were five minutes remaining in the warm-up. At 58 and 59 minutes post absorption, the subject was instructed on the amount of time remaining in the warm-up, and was asked if he would be ready to start at one hour post-absorption. If the subject was not ready at this time, they were given an extra one to two minutes to finish their warm-up. At one hour post-absorption the subject was asked to start pedaling faster as the resistance was set on the ergometer. As the subject began to pedal faster, the resistance was set; the first two minute sprint officially began when the resistance was set and the "Start" command was given. When the start command was given, the subject began a maximal sprint and the research assistant started the timer on the computer. Verbal encouragement and instructions were provided during each two minute sprint (Appendix D) and the "Stop" command signaled the end of each two minute sprint. At the same time the two minute sprint ended, a separate stopwatch was started to measure the rest phase. After starting the rest phase timer, heart rate was measured and called out to the research assistant. During the rest phase, subjects did not pedal. This time was also used by the research assistant to record measurements displayed on the computer screen and then reset the computer for the next two minute interval. The subject was informed of the time at 30, 45, and 55 seconds during the rest phase of the test (Appendix D). At exactly one minute, the start command was given and the next sprint began as described above. This process was repeated seven more times until the subject had completed eight 2-minute sprints.

A clock was placed in view of the subject to keep them aware of the time remaining in each two minute sprint. For the first sprint, the research assistant started both the computer timer as well as the clock provided for the subjects. This allowed the individual providing instructions to set the resistance and give the "Start" command. For the remaining sprints, where the resistance was already set, the individual providing the feedback and instructions started and stopped the subject's clock.

Verbal encouragement and instructions were provided at the same time intervals and with the attempt to provide the same level of enthusiasm for every subject during all sprint tests (Appendix D). A single individual provided all instructions and feedback necessary for testing. For a detailed outline of the timeline and procedures followed during the sprint tests see Appendix F.

Measurements of heart rate were recorded at the end of each two minute sprint and monitored continuously as an indicator of overall cardiovascular work (ACSM, 1991) . For each two minute sprint interval, measurements of power output were calculated.

Statistical Analysis

The statistical evaluation of the data included descriptive statistics for age, height, weight, body fat percentage, VO2max, and mean power output for all sprints during both the caffeine and placebo trials. A two-way analysis of variance with repeated measures was calculated to compare mean power output for the second through seventh work intervals of the two sprint tests.

One-way analysis of variance with repeated measures and Tukey post-hoc analysis were used to determine the location of the significant drop in power detected by the two-way analysis of variance.

Mean power output measured in watts per kilogram was analyzed on intervals two through seven only. The first interval was labled a warm-up interval due to the variations in mean power output during this interval. Subjects needed one interval of warm-up to prepare themselves for a maximal effort for the remainder of the testing. The eighth interval was not analyzed due to variability in this data as well. In all but one sprint test, mean power output increased from interval seven to interval eight. This was a result of the subjects being informed of the last interval.

Level of Significance

A probability level (p) of .05 or less was selected as the level of statistical significance for all data analyses.

Chapter IV

Results and Discussion

Introduction

This chapter is organized in several sections as follows: scoring of the data, analysis of the data, discussion of findings, conclusions, and weaknesses of this study.

Scoring of the Data

Data for 19 trained cyclists aged 20-40 years were analyzed. Data on one subject were not included due to a lack of reliability between the two sprint tests for this subject. The design of the sprint test was believed to cause a consistent drop in mean power output for each two minute sprint as each subject progressed through the test. A consistent drop in power was noted during this subject's first sprint test. However, during this subject's second sprint test, mean power output for each consecutive two minute interval increased consistently throughout the test. This indicated that the subject did not exert a maximal effort during all sprints in both testing situations, making this data unreliable. Following the first sprint test, this subject expressed concern about the difficulty of the sprint test.

Analysis of Data

Table 1 summarizes data collected on VO2max and all anthropometric measurements. Appendix G contains individual data for all subjects. Subjects ranged in age from 20 to 40 years and in weight from 64 to 93.5 kilograms. The mean body fat percentage was 11.2 percent and this value ranged from 5.9 to 19.1. The average VO2max was 63.1 ranging from 56.1 to 73.5. Upon comparison to data collected by the American College

Table 1

Description of Subjects (N = 19)

	Age(yrs)	Weight(kg)	Fat %	VO2max(ml/kg/min)
Mean	30.6	81	11.2	63.1
SD	5.9	8	3.8	5

Table 2

Mean Power Output Measured In Watts Per Kilogram During Trials Two Through Seven Following Caffeine and Placebo

	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7
Caff	4.708 (.413)	4.547 (.462)	4.385 (.424)	4.288 (.433)	4.274 (.411)	4.229 (.402)
Plac	4.607 (.479)	4.451 (.424)	4.360 (.409)	4.246 (.430)	4.169 (.448)	4.178 (.437)

Note. Values are expressed in watts/kg and represent the mean (plus or minus the SEM). Two-way analysis of variance revealed no significant (p = .18) differences in power output between caffeine and placebo trials.

of Sports Medicine, the values recorded during this investigation for maximal oxygen consumption place this subject population above the 95th percentile rating. In other words, these data confirm that these individuals were highly trained cyclists.

Table 2 summarizes mean power output in watts per kilogram for intervals two through seven for both the caffeine and placebo trials. Appendix H contains individual sprint test data. Two-way analysis of variance with repeated measures comparing mean power output for the second through seventh work intervals during both the caffeine and placebo trials indicated no significant differences ($p = .18$). However, a trend toward increased power output during the caffeine trial was evident (Figure 1). Analysis indicated a similar trend in the decrease in power output from trials 2 through 7 for both the caffeine and placebo trials. A significant decrease in power output was noted.

Table 3 summarizes data from the two-way analysis of variance comparing mean power output during trials 2 through 7 for the caffeine and placebo trials.

To analyze the significant drop in power detected by the two-way anova, two one-way analysis of variance with repeated measures and Tukey post-hoc analysis (Keppel 1982) were performed on both the caffeine and placebo trials. The results of these tests indicated a significant drop in power during both the caffeine ($p = .001$) and placebo ($p = .001$) trials. During the caffeine trial, power output dropped significantly from trials two through four. During the placebo trial power output dropped significantly from intervals two to three only. Table 4 summarizes data from the Tukey post-hoc analysis.

Figure 1

Mean Power Output for Caffeine and Placebo Trials

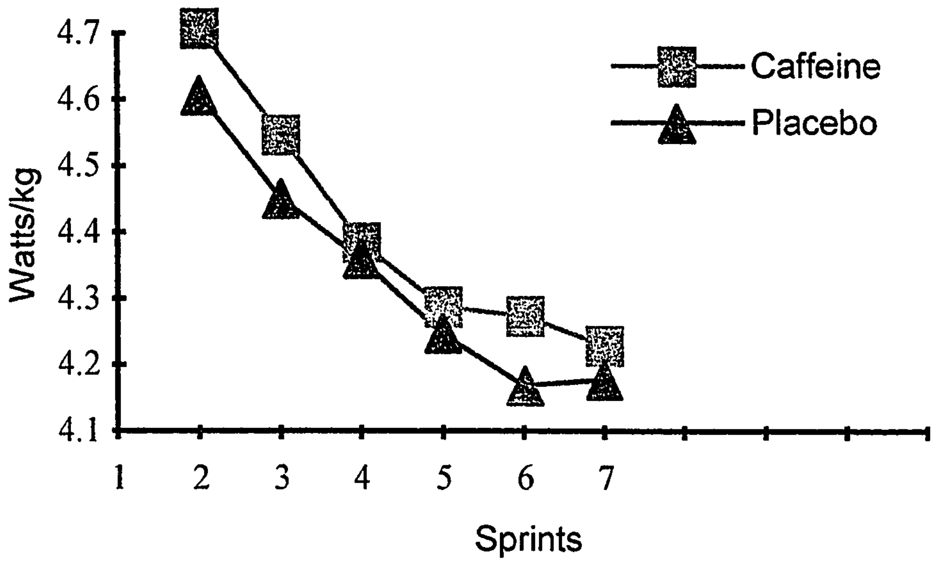

Table 3

Two-way Analysis of Variance for Mean Power Output During Sprint Trials Two Through Seven.

	F	df	p
Caffeine vs. Placebo	1.94	1	.181
Trials	74.72	5	<.001
Interaction	.74	5	.598

Table 4

Results of the Tukey Post-hoc Analysis for the Caffeine and Placebo Trials. Values Represent differences in mean power output between trials. Values greater than .134 represent significant differences (* = $p < .05$) in mean power output between trials.

Caffeine Trial

Trial	2	3	4	5	6	7
2	-	-	-	-	-	-
3	0.161*	-	-	-	-	-
4	0.323*	0.162*	-	-	-	-
5	0.42*	0.259*	0.097	-	-	-
6	0.434*	0.273*	0.111	0.014	-	-
7	0.479*	0.318*	0.156*	0.059	0.045	-

Placebo Trial

Trial	2	3	4	5	6	7
2	-	-	-	-	-	-
3	0.156*	-	-	-	-	-
4	0.247*	0.091	-	-	-	-
5	0.361*	0.205*	0.114	-	-	-
6	0.438*	0.282*	0.191*	0.077	-	-
7	0.429*	0.273*	0.182*	0.068	0.068	-

Discussion of Findings

The purpose of this study was to measure the effects of caffeine on short term, high intensity exercise. Many studies have shown benefits to caffeine ingestion during prolonged moderate intensity exercise (Berglund & Hemmingson, 1982; Cadarette et al., 1983; Costill et al., 1978; Graham & Spriet, 1991; Ivy et al., 1979; Sasaki et al., 1987). The benefits of caffeine ingestion prior to endurance exercise are attributable to caffeine's effect on increasing free fatty acid metabolism and the resulting glycogen sparing effect. Butts and Crowell (1985), Costill et. al., (1978), and Ivy et al., (1979) all reported benefits of caffeine ingestion prior to endurance exercise and also found increased levels of free fatty acids in the blood during the caffeine trial. However, during other types of exercise the findings are not as clear. In an extensive literature review, Dodd et al. (1993) reported no benefits of caffeine ingestion on performance during graded, incremental exercise. During high intensity exercise, Williams (1991) reported no increases in maximal voluntary contractions, maximal power output, or any delay in fatigue following caffeine ingestion.

The main problem with the research measuring caffeine's effect on short term, high intensity exercise has been its lack of an attempt to measure caffeine's glycogen sparing effect. More recently, however, Trice and Haymes (1995) studied the effects of caffeine ingestion (5mg/kg of body weight) during high intensity, intermittent exercise and found significant increases in time to fatigue following caffeine ingestion. Although similar to the present study, this investigation differs in several ways. The total test time was longer (30 minutes) and the work intervals were shorter (only one minute) . Subjects in the Trice and Haymes investigation were encouraged to complete three 30 minute exercise periods in which they continued to exercise for one minute and rest for one minute. Each 30 minute exercise period was separated by five minutes of rest. The intensity level was determined by VO2max and not body weight. And most importantly, subjects were asked to maintain 70 rpm during the one minute intervals. Although subjects were working at 85-90% of their VO2max, this pedaling rate is somewhat slow and cannot be compared to the faster speeds of contractions found in the muscles during high intensity activities such as basketball, hockey, soccer, or football. In fact, as a result of the pedaling rate and duration of exercise, this 30 minute test becomes like an endurance event. This might help to explain why Trice and Haymes (1995) found benefits of caffeine ingestion when the present study did not.

Other studies measuring caffeine's effect on short term, high intensity exercise are more difficult to compare as a result of the variability in their testing protocols. Collomp et al. (1992) measured the effects of caffeine during a 100 meter swim at maximum speed and found benefits of caffeine ingestion in the trained subjects only. Subjects in this study performed only one sprint that was much shorter in duration than the sprints performed during the present investigation. Anselme et al. (1992) used a force velocity test on the cycle ergometer to measure the effects of caffeine, and found increases in maximal anaerobic power during the caffeine trial. The sprints for this test were only 6 seconds in duration and separated by 5-minute rest periods. Williams et al. (1988) measured the effects of caffeine ingestion on performance during a 15 second sprint on the cycle ergometer and found no benefits. While Collomp et al. (1991) measured the effects of caffeine ingestion on performance during the Wingate test and also found no benefits. Finally, Bond et al. (1986) used maximal contractions on a Cybex machine and found no benefits of caffeine ingestion for isokinetic flexion or extension of the knee. It is interesting that two of these investigations report benefits of caffeine ingestion during very short bouts of high intensity exercise. However, they are difficult to compare to the present study due to a lack of similarity in the testing protocols. As a result of the shorter testing protocols, the body is using mostly anaerobic sources for energy and caffeine's glycogen sparing effect cannot be measured.

Presently, a lack of agreement exists regarding caffeine's effects on short term, high intensity exercise. In addition, research measuring caffeine's glycogen sparing effect during this type of exercise is limited. Therefore, it was the purpose of this investigation to measure the effects of caffeine ingestion on short term, high intensity exercise. The sprint test, consisting of eight two minute sprints separated by one minute of rest, was designed to theoretically measure the carbohydrate sparing effect of caffeine during short term, high intensity exercise. This test was much shorter than the one reported by Trice and Haymes (1995) and was more of an anaerobic test. A two minute interval was theorized to be of sufficient duration to promote utilization of the anaerobic energy systems while promoting an increased use of fat as an energy source. By performing eight intervals with a limited rest time it was also theorized that a significant level of fatigue would be produced to allow comparison between the caffeine and placebo trials. Based on the results of the two-way analysis of variance, a significant drop in power output was achieved during both the caffeine and placebo trials. One-way analysis of variance and

Tukey post hoc analysis (Keppel, 1992) indicated that this drop in power output was consistent from intervals two through four during the caffeine trial and from intervals two to three during the placebo trial. One problem encountered was that subjects seemed to have difficulty pacing themselves for the entire duration of the test. As a result, a consistent maximal effort may not have been achieved during every two minute interval.

Dodd et al. (1991) reported no significant differences in VO2max and anaerobic threshold when comparing caffeine naive and caffeine habituated subjects. They also reported similar increases in free fatty acid concentrations for both groups. During the present investigation blood samples were not taken and no attempt was made to distinguish caffeine consumption levels prior to testing. However, it did appear that the subjects who indicated they were not caffeine consumers experienced more of the neuromusculatory effects of caffeine. These effects included an increased heart rate, mental alertness, jittery feelings, and an overall sense of euphoria as a result of the caffeine's stimulation of the central nervous system. These effects did not translate into increased power output.

In one extreme case, where the subject indicated a very high level of caffeine consumption, the results were interesting. First, this subject expressed difficulty refraining from caffeine consumption during testing. Second, despite a similar drop in power during both tests, power output was approximately 100 watts higher during all intervals during the caffeine trial. It appeared that as a result of the withdrawal from caffeine, performance was negatively effected. In other cases, where subjects indicated difficulty in refraining from caffeine, no obvious differences were apparent in performance levels.

Many of the subjects were able to distinguish between the caffeine and placebo trials based on the taste of the solution, the neuromuscular facilitory effects of caffeine, or both. Crystal light lemonade did not appear to be a good means of masking the taste of caffeine, as many subjects had complaints about the taste of the lemonade when it had the caffeine dissolved in it. Upon completing the second sprint test, each subject was asked to attempt to distinguish between the caffeine and placebo trials. In all but one case, in which the subject did not guess, the subjects were able to distinguish between the caffeine and placebo trials. This did not appear to affect the reliability of the test, however, for two reasons. First, the sprint test was very physically demanding and helped to minimize the possibility of a Hawthorne Effect. Second, many of the subjects based their determination of the caffeine trial on the fact that they could not sleep the night of the caffeine trial. Therefore, they were not certain that it was the caffeine trial until after the test was completed.

There also appeared to be a positive relationship between the subject's VO2max and performance on the sprint tests. Although not tested statistically, it appeared that a higher VO2max resulted in an ability to exert a more consistent effort throughout the sprint test. These subjects appeared more efficient at pacing themselves throughout the test which allowed them to exert a true maximal effort from one interval to the next. The sprint test, while still producing a consistent drop in power for these subjects, did not appear to be as demanding.

Conclusion

Based on the findings of this study it is the conlusion of this investigator that caffeine ingestion in the amount of 5mg/kg of body weight does not improve the performance of highly trained cyclists during repeated bouts of high intensity exercise.

Weaknesses of this Study

The weaknesses of the current investigation include a lack of statistical power, due to a low number of subjects. The subjects' lack of familiarity with the cycle ergomoter posed a minor problem; subjects wanted to bring their own pedals and seats to attach to the ergometer. They indicated that this would make them more comfortable. This was not possible due to the differences in the pedal sizes between a regular bicycle and the cycle ergometer. This may have limited the subjects from exerting a true maximal effort. In addition to being unfamiliar with the cycle ergometer, subjects were also unfamiliar with the sprint test. No subject had previously experienced a test like the sprint test. Furthermore, the use of Crystal Light lemonade was not sufficient to mask the taste of caffeine in all cases. Many of the subjects complained of the taste of the Crystal Light solution when the caffeine was dissolved in it. This may have influenced their performance during the ensuing sprint test. The failure to distinguish between caffeine consumption levels of the subjects may also have confounded results. Based on observations made and feedback provided by subjects during the sprint testing, the effects of caffeine appeared varied depending on the individual's normal caffeine intake. And finally, limiting the subject population to males limits the generalizability of the results. The effects of caffeine on exercise performance by women may be different.

Chapter V

Summary, Conclusions & Recommendations

Introduction

The contents of this chapter includes an introduction followed by sections on the statement of the problem, a summary of the procedures used for this investigation, conclusions, recommendations, and concluding remarks.

Statement of the Problem

The research regarding short term, high intensity exercise is unclear. According to Dodd et al. (1993) , the majority of research on animals has consistently shown caffeine to enhance muscle force production, while human studies continue to show no benefits of caffeine during short term, high intensity exercise. However, this is problematic. First, with animal studies very high doses of caffeine are administered, making generalization to humans impossible. Second, this research (Bond et al., 1986; Williams et al., 1988) has focused on caffeine's effect on isolated muscle, specifically caffeine's enhancement of calcium release and its effect on isolated muscular contractions. Lastly, many studies examining caffeine's effect on performance (Anselme et al., 1992; Collemp et al., 1991; Collemp et al., 1992) , have used testing protocols that were not long enough to measure caffeine's glycogen sparing effect. Also, these testing protocols do not warrant generalization to any specific athletic setting.

During short term, high intensity exercise, the main source of energy is carbohydrates, and the main cause of fatigue in exercise is carbohydrate depletion (McArdle et al., 1991).

The purpose of this investigation was to examine the effects of caffeine on repeated bouts of short term, high intensity exercise where the glycogen sparing effect of caffeine may play a vital role.

Summary

A non random method of subject selection was used for this investigation. Twenty highly trained male cyclists aged 20 - 40 were chosen to participate in this investigation. A highly trained cyclist was defined as one who had averaged 100 miles per week or more during training and competition for a period of one year leading up to this investigation.

For the calculation of VO2max, a graded exercise test was administered and measurements of heart rate, ventilation, and expired gases were taken. Tests of VO2max were performed on a cycle ergometer using the Medgraphics CPX-D Metabolic Cart and a Nikon-Hoden electrocardiograph. These tests were administered first and were followed within a one week time period by the two sprint tests. Each subject served as their own control by performing the sprint test once after caffeine ingestion (5mg/kg of body weight in 400ml of lemonade), and once following ingestion of a placebo (400ml of lemonade only). The sprint test consisted of eight 2-minute maximal sprints on the cycle ergometer at a resistance level set to .045kg/kg of body weight. Sprints were separated by one minute of rest during which the subjects remained seated on the ergometer and did not pedal. All subjects performed a warm-up on the cycle ergometer of ten to fifteen minutes in duration and at a self selected pedal cadence and resistance level. Verbal encouragement was administered at selected times during each two minute sprint with the same level of enthusiasm for every subject.

For each two minute sprint, a measurement of mean power output was calculated using Sports Medicine Industries Power Program, version 1.02, on an IBM computer. The program was set to run for 120 seconds. Measurements of heart rate were also taken at the end of each two minute sprint using the Polar, "Favor Model" heart rate monitor.

Results of a two-way analysis of variance indicated a significant drop in power output, measured in watts/kg, during both the caffeine and placebo trials. During both trials this drop in power existed from trials two through four and then leveled out. However, no significant differences ($p = .18$) in mean power output, measured in watts/kg , were found between the caffeine and placebo trials. There was also no significant interaction between tests and sprints.

Recommendations

For future studies of the effects of caffeine on short term, high intensity exercise the following recommendations are made.

First, the results of this investigation indicated that there was a trend toward increased power output during the caffeine trial. Therefore, future studies should consider using increased amounts of caffeine, perhaps 10mg per kg of body weight, should be pursued.

Second, subjects should be allowed an opportuntiy to familiarize themselves with the cycle ergometer and the sprint test by adding a third sprint test to the research protocol. The purpose of this test would be a practice test and would include the administration of the sprint test without the ingestion of either caffeine or placebo. This would give the subjects an opportunity to familiarize themselves with the sprint test as well as the cycle ergometer and allow for more consistent maximal efforts during the following sprint tests.

Third, the use of each subject's own bicycle, if possible, would make them feel more comfortable and probably help produce a more realistic maximal effort.

Fourth, an attempt should be made to distinguish between caffeine naive and caffeine habituated subjects. It appears that the results of this study may have varied based on each individual's level of caffeine consumption. Future research should account for these differences by placing subjects into different groups based on their caffeine consumption levels and analyzing the differences.

Fifth, it may be more beneficial to determine the workload during the sprint test based on values calculated during the VO2max test. During this investigation, it appeared that using the subjects' body weight to calculate equal relative workloads did not always work. The heavier subjects seemed to be at a disadvantage as a result of their resistance level being much higher. Future research should include pilot work using individuals within their proposed subject population to determine the effectiveness using either the subject's VO2max or body weight to determine workload.

Sixth, attempts should also be made to measure gas exchange paramters and serum free fatty acid levels in the blood during the sprint tests. This would provide additional information and help to explain results. This data would be especially helpful in determining whether caffeine is an effective glycogen sparer during this type of exercise.

Seventh, caffeine administered in the form of a pill would be more beneficial. This form of caffeine is easier to administer and prevents the problem of having to mask the taste of the caffeine.

Eighth, during the sprint tests, subjects should be allowed to pedal during the resting periods. Athough it is difficult to standardize the pedaling rate during this time, many of the subjects experienced difficulty in recovering during the one minute rest period as they were not allowed to pedal. This may have affected their effort during each successive two minute sprint interval.

And finally, future research using this type of a sprint test necessitates the use of highly trained cyclists. The sprint test used for this investigation was very physically demanding, and the use of subjects who are not highly trained athletes may produce poor results. The use of highly trained cyclists during this investigation was extremely helpful as these subjects were very familiar with this form of exercise and were also highly motivated. Highly trained athletes in other types of activities may experience difficulty with this sprint test. Using subjects who are not highly trained cyclists may necessitate the use of VO2max to determine workloads.

Concluding Remarks

More research is needed in this area. The design of the test for this study was sufficient to cause a significant drop in power across test intervals allowing a comparison between the caffeine and placebo trials. However, although a trend toward increased power output was evident ($p = .18$) during the caffeine trial, no significant differences in mean power output were found between the caffeine and placebo trials. It has been theorized by the researchers of this investigation that a higher dose of caffeine, perhaps 10mg/kg of body weight, may have produced a significant difference in mean power output. Future research is needed to substantiate this theory. This investigation is the first step in attempting to measure caffeine's glycogen sparing effect during short term, high intensity exercise. This study has identified some of the problems and considerations inherent in attempting to measure caffeine's influence on this type of performance. Researchers will hopefully use this investigation as a basis for future study.

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APPENDIX A

Health Screening Questionnaire

SAN JOSE STATE UNIVERSITY, DEPARTMENT OF HUMAN PERFORMANCE

MEDICAL & ACTIVITY HISTORY QUESTIONNAIRE

All information will be kept confidential. This information will be used in evaluating your readiness for an exercise program. Please make this record as accurate and complete as possible. Print or type for easy legibility.

Name ____________________ Phone ____________

Address (street, city, zip)______________________________

Personal Physician (local):____________________

Address: ____________________ Phone: __________

Person to Contact in Case of an Emergency:____________________

Relationship to you: ____________________

Daytime Phone #: (______)______________

Demographic Information:

Age (yrs) ______ Sex _____ Height (ins) ______ Weight (lbs) ______

Medical Information (Check if yes)

Past History: In the past have you ever had:

☐ Heart attack or stroke	☐ Rheumatic fever	☐ Heart murmur
☐ Heart surgery	☐ Heart rhythm problems	☐ High blood pressure
☐ Disease of arteries	☐ Varicose veins	☐ Lung disease
☐ Injuries to back, knees, ankles	☐ Epilepsy or convulsions	☐ Diabetes
☐ Allergic reactions	☐ Tuberculosis	☐ Bronchitis
☐ Asthma	☐ Arthritis	☐ Abnormal chest X-ray
☐ Unusual dizziness	☐ Fainting spells	☐ Scarlet fever
☐ Anemia	☐ Thyroid problems	☐ Urinary tract problems
☐ Elevated cholesterol	☐ Hernias	☐ None of the Above

Family History: Have any blood relatives had: (include parents, sisters, brothers, grandparents)

☐ Heart attack under age 50	☐ Strokes under age 50	☐ Heart operations
☐ High blood pressure	☐ High cholesterol	☐ Diabetes
☐ Congenital heart disease	☐ Asthma or hay fever	☐ Obesity
☐	☐	☐ None of the above

Present Symptoms: Have you recently (in the past 6 months) had:

☐ Chest pain or pressure	☐ Shortness of breath	☐ Heart palpitations
☐ Light headedness	☐ Cough on exertion	☐ Coughing up blood
☐ Back pain	☐ Arthritis	☐ Swollen legs
☐ Awakened short of breath	☐ Loss of consciousness	☐ Joint soreness
☐ Chronic muscle soreness	☐	☐ None of the above

Please explain any conditions checked above (specific condition, date of event, etc).

____

____

____

List prescribed or self-prescribed medications or diet supplements you now take.

____

____

____

> > > > OVER > > > >

fn: research med hist revised: 3/9/95

Date of last complete physical exam (month, year): ______________ ( ) can't remember
Date of last chest X-ray (month, year): ______________ ( ) can't remember
Date of last electrocardiogram (ECG) (month, year): ______________ ( ) can't remember
Were any of the above abnormal? ( ) yes ( ) no

Have you ever had any major chronic skeletal or muscular injuries? ( ) yes ( ) no
If yes, explain:

____
____

List any hospitalization in past 10 years, include dates and reasons for hospital stay:

____
____
____

Explain any other significant medical problem that you consider important for us to know.

____
____
____

Lifestyle Information

Have you ever smoked cigarettes, cigars or a pipe? ( ) yes ( ) no
Do you presently smoke? ( ) yes ( ) no If no, when did you quit (year)? ________

What was your body weight (in pounds) one year ago? ________ at age 21? _______
Have you gained ( ) or lost ( ) weight in the last 2 months? How many pounds? _______
What is the most you have ever weighed (pounds)? _____

Are you currently involved in a regular exercise program? ( ) yes ( ) no
If yes indicate the kind of activity and number of days per week:

Activity	Days/week
____________________	__________
____________________	__________
____________________	__________

In the past 2 months, what is the average number of miles you cycle each week?
___ 50-75 ____75-100 ___100-150 ___150-200 ___>200

Other Information

How would you describe your general health?
( ) poor ( ) fair ( ) average ( ) good ( ) excellent
Have you ever been advised by a physician not to exercise because of a medical problem?
( ) yes ( ) no If yes, please explain:

____
____
____

I certify that, to the best of my knowledge, the above answers are accurate and true. I have read the fact sheet and 'rules' on equipment usage, and will comply.
Signature ________________________ **Date** __________

For office use only:
Risk factor evaluation by __________

fn: research med hist revised: 3/9/95

SJSU SAN JOSE STATE UNIVERSITY

College of Applied Sciences and Arts • *Department of Human Performance*
One Washington Square • San José, California 95192-0054 • 408/924-3010 • FAX 408/924-3053

APPENDIX B

Informed Consent

AGREEMENT TO PARTICIPATE IN RESEARCH

Responsible Investigator: John C. Ashworth
Title of Protocol: The effects of caffeine ingestion on performance during short term, high intensity exercise.

1. I have been asked to participate in a research study investigating the effects of caffeine ingestion on performance during short term, high intensity exercise.

2. I will be asked to complete a health history and bicycling experience questionnaire, and an agreement to participate in research. I will be asked to perform a VO2max test. In addition I will be asked to perform a test involving eight maximal sprints on a cycle ergometer, each lasting two minutes, and each separated by one minute of rest. I will perform this test twice, once after ingesting caffeine dissolved in a lemonade drink, and once after ingesting the lemonade without the caffeine. Caffeine will be in the amount of 5mg/kg of my current body weight. I will also be asked to have the following measurements taken: height, weight, skinfold measurements, resting and exercising blood pressure and heart rate. All of the above will be performed at San Jose State University during the 1994-95 Academic year.

3. Possible risks and/or discomforts: The caffeine may cause an increased heart rate, nervous irritability, irregular heart beat, nausea, or shortness of breath as a result of caffeine ingestion. You may experience some discomfort and/or dryness in the mouth, throat, and chest during exercise on the cycle ergometer. You may feel light headed or fatigued for a short time following these procedures. You will experience an increase in heart rate and breathing rate, sweating, and an increased body temperature, as well as increased blood pressure. Discomfort and/or redness may result from the electrocardiogram electrodes during testing. During high intensity exercise, abnormal heart beats may occur. If abnormalities are detected in electrocardiographic recordings, the test will be stopped immediately and you will not be included as a subject in this study. There may be some bruising or pinching from skinfold measurements. A CPR certified person and ACSM certified exercise specialist or test technician will be presnt for VO2max testing.

4. I will benefit from participation in this study by receiving information regarding my VO2max, body composition, and physical characteristics (height, weight, and resting blood pressure) .

5. All data collected from participation in this study may be used for medical and/or scientific purposes, including publication and presentation at professional conventions and events. My identity for individual test results will not be revealed in published or presented papers without my written consent.

6. I understand that I will not be compensated for my participation in this study.

7. Any questions about the research may be addresses to John C. Ashworth (principal investigator) , at (510)934-3280. Complaints about the research may be presented to Dr. James Bryant, Chairman of Department of Human Performance, at (408)924-3010. Questions or complaints about research, subjects' rights, or research-related injury may be presented to Serena Stanford, Ph.D., Associate Vice President of Graduate Studies and Research, at (408)924-2480.

8. No service of any kind, to which I am otherwise entitled, will be lost or jeopardized if I choose to "not participate" in the study.

9. Having read the above, I agree that my consent is given voluntarily without being coerced. I understand that I may withdraw from this study at any time (including during testing), without prejudice to my relations with the Department of Human Performance, San Jose State University, the principal investigator, or their associates.

10. I understand that I will receive a signed and dated copy of the consent form. The returned copy of this consent form indicates agreement and confirmation of my being fully informed of my rights.

My signature indicates that I have agreed to participate in this study.

____

Subject's Signature Date

____

Investigator's Signature Date

APPENDIX C

Pre-test Instruction Sheet

*Following is a list of general instructions regarding this research project so that you know what to expect and what you should be doing in terms of eating and exercise during the period of time in which you will be tested.

****Testing Procedures:**

As we may have talked about on the telephone, I am attempting to measure the effects of caffeine on exercise performance. You will be asked to participate in three different tests, including the VO2max test which will be performed first. Once you have performed the VO2max test the two sprint tests will take place sometime during the following week. All three tests will be performed on separate days with at least 48 hours separating each test. All three tests should take place within a one week time period.

The sprint tests will consist of eight two minute sprints, each separated by one minute of rest on the cycle ergometer. Your goal for this test will be to perform as much work as possible during each two minute sprint and across all eight trials. You should have nothing left after the eighth trial has been completed. Upon arriving to the laboratory for each sprint test, you will ingest a lemonade flavored crystal light beverage and will then be required to sit passively for approximately one hour. Please bring something to read to pass the time. You should plan for this testing session to last approximately 1 1/2 hours.

The VO2max testing session will last approximately one hour.

****Eating and Exercise Guidelines For All Testing Procedures:**

Please do not eat 3 - 4 hours before any of the tests. Otherwise, your eating habits do not need to change for this research project. Please maintain your normal diet throughout the entire testing process.

You will be required <u>not to</u> exercise for three hours prior to any of the tests, and to refrain from any exhaustive exercise in the 24 hours prior to any of the three tests.

You should also obstain from caffeine consumption for one week prior to any of the testing and throughout the entire testing period. This includes caffeine found in foods such as chocolate, soda, coffee, etc.

****What To Bring:**

-Your signed Informed Consent and Medical History forms: we cannot proceed without these documents!

-One or two towels.

-A water bottle

-Proper clothing - whatever you feel comfortable riding in.

-Something to read: you won't need something to read for the VO2max test.
-Anything else you think you may need.

Note: If you have any questions or are concerned about anything please feel free to give me a call at either of the following numbers:

w(408)924-1390
h(510)934-3280

As it is now summer vacation and I am not spending too much time in my office at school, you are more likely to reach me personally at home. Please feel free to call me collect any time. I do check my voice mail at school about every other day as well. So if you call the 408 number you can expect a return phone call within two days at the most.

Thanks again,
John Ashworth

APPENDIX D

Verbal Feedback given During Sprint Tests

For each sprint interval, the commands and verbal encouragement and feedback were administered as follows:

00sec - " Start pedaling faster, START! "

30sec - " 30 seconds in, come on __name___, looking good, here we go. "

60sec - " One minute to go, good job, keep it up, keep it up "

90sec - " 30 seconds to go, stay with it now__name__, push it, push it. "

105sec - " 15 seconds, come on push it, almost there, almost there"

115sec - " 5 seconds. "

120sec - " STOP! "

During the one minute resting period the following feedback was administered:

30sec - " 30 seconds. "
45sec - " 15 seconds. "
55sec - " 5 seconds. "
60sec - " Start! "

APPENDIX E

Instructions Administered Before Each Sprint Test

After completing your warm - up, I will ask you if you are ready. If you are then I will instruct you to start pedaling as fast as possible as I begin to set the resistance. The first interval will officially begin on my "START" command. I will inform you of the time during each trial at 30 seconds, 60 seconds, 1 1/2 minutes, 1 3/4 minutes and when there are 5 seconds remaining. You will stop pedaling at the end of each two minute interval on my "STOP" command, and will be required not to pedal during any of the resting periods. You will also be required to remain seated on the bike at all times, except at the beginning of trials two through eight where the resistance will already be set. For the start of these trials you may stand to get started, but you must sit back down immediately and continue pedaling. Once the testing has begun, it is important that we keep going until the test is completed.

Your goal for this test is to perform as much work as possible, which means sprinting as hard as you can, for each two minute interval and throughout the entire test which includes eight successive intervals. You should have nothing left at the end of each two minute interval, but should be able to adequately recover during the one minute rest period so that you can repeat this process for each successive interval over eight trials. Upon completion of the last interval, you should feel like you could not perform another one. You will only be informed of which interval you are on when you are on your last one.

Brief Instructions Just Prior To Testing

Remember, you will begin each two minute interval on my start command, and you will stop on my stop command. Your goal again is to perform as much work as possible during each two minute interval and throughout the entire test.

APPENDIX F

Outline of the Time-line and Procedures

1. **Arrival:**
   - Subject ingests caffeine within 5 minutes of arrival to lab.
   -Timer was started to measure absorption time of caffeine.

2. **Following ingestion:**
   -test instructions were read to the subject.
   -subject then performed non-strenuous sitting tasks for 45 minutes.
   -subjects were also asked at this time about how long they would need for a warm - up.

3. **At 45 minutes post absorption:**
   -subjects were asked if they need to use the bathroom, if they had not gone already?
   -at this time the heart rate monitor was also attached to the subject.
4. **At 50 minutes post absorption:**
   -subject began warm-up.

5. **At 58 minutes post absorption:**
   -subject was asked if they would be ready in two minutes.

6. **At 60 minutes post absorption:**
   -subject asked to begin pedaling faster as resistance was set.
   -when resistance was set, testing was started.

7. **For each sprint interval, commands and encouragement were administered as follows:**
-Subject informed of the time at 30, 60, 90, 105 and 115 seconds.
-Encouragement was administered at these intervals. Motivational statements include:
00sec - " Start pedaling faster, START! "
30sec - " 30 seconds in, come on __name___, looking good, here we go. "

60sec - " One minute to go, good job, keep it up, keep it up "

90sec - " 30 seconds to go, stay with it now__name__, push it, push it. "

105sec - " 15 seconds, come on push it, almost there, almost there"

115sec - " 5 seconds. "

120sec - " STOP! "

During the one minute resting period the following feedback was administered:

30sec - " 30 seconds. "
45sec - " 15 seconds. "
55sec - " 5 seconds. "
60sec - " Start! "

8. This same procedure was followed until all eight sprint intervals were completed.

APPENDIX G

Description of Subjects (N=19)

Subjects	Age (yrs)	Weight (kg)	Fat %	VO2max (ml/kg/min)	Avg. Miles/Wk
1	26	79.5	15.4	66.4	100-150
2	40	74.1	16.1	61.1	100-150
3	27	86	10.9	60.3	150-200
4	34	78.8	10	58	>200
5	20	64	5.9	73.5	100-150
6	28	84.9	11.3	56.1	100-150
7	22	79.6	14	64.5	100-150
8	26	80.9	8.4	61.8	>200
9	27	77.1	6	71	>200
10	33	93.5	13.7	58.5	100-150
11	35	91.9	16	58.1	100-150
12	36	92.8	13.4	64.2	100-150
13	40	87.3	19.1	56.2	>200
14	25	66.3	7.2	70.3	150-200
15	32	80.9	9	66.1	150-200
16	28	78.7	6.9	65.5	150-200
17	31	86.2	7.6	64.1	>200
18	40	74.4	11.2	63	100-150
19	31	81.6	10	60.2	100-150

APPENDIX H

Power Outputs (Watts) and Heart Rates (bpm)

Name:	**Subject #1**	**Date: 4/12/1995**	**Temp.: 22 C**	**Warm - up:**
Test #	**1(Caffeine)**	**Time: 3:00pm**	**Res.: 3.58kg**	**Time: 15 Res.: 1-2.75**

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	392	433	339	177
2	389	421	356	170
3	364	410	328	180
4	324	378	280	179
5	306	354	271	178
6	296	324	268	180
7	304	332	279	177
8	299	327	276	179

Name: Subject #1	Date: 4/14/1995	Temp.: 20 C	Warm - up:
Test # 2(Placebo)	Time: 6:00pm	Res.: 3.58kg	Time: 12 Res.: 1-3.25

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	374	424	329	169
2	342	380	309	171
3	324	374	296	172
4	322	365	294	175
5	322	358	301	177
6	314	352	293	177
7	312	345	289	176
8	313	354	283	176

Name: Subject #2		Date: 4/10/95	Temp.: 18 C	Warm - up:
Test #	1(Placebo)	Time: 3:30pm	Res.: 3.33kg	Time: 7 Res.: 1.5kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	340	415	304	172
2	315	363	275	175
3	309	366	281	177
4	305	357	281	182
5	300	337	284	182
6	298	333	278	183
7	299	330	285	184
8	313	357	287	188

Name: Subject #2 **Date: 4/14/95** **Temp.: 20 C** **Warm - up:**

Test # 2(Caffeine) **Time: 3:30pm** **Res.: 3.33kg** **Time: 10**
Res.: 1.25

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	350	405	318	181
2	332	398	290	186
3	307	351	276	189
4	299	332	277	190
5	295	314	278	190
6	293	318	274	192
7	295	347	273	191
8	315	345	287	197

Name: Subject #3 **Date: 5/12/95** **Temp.: 21C** **Warm - up:**

Test # 1(Placebo) **Time: 5 :30pm** **Res.: 3.87kg** **Time: 15min**
Res.: 2.25

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	430	459	406	177
2	428	442	412	184
3	411	426	396	186
4	413	427	388	185
5	400	407	390	187
6	398	418	375	188
7	385	396	351	189
8	399	414	388	189

Name: Subject #3 **Date: 5/14/95** **Temp.: 18.5C** **Warm - up:**

Test # 2(Caffeine) **Time: 4:30pm** **Res.: 3.87kg** **Time: 15min** **Res.: 2.25**

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	433	467	417	179
2	432	452	419	186
3	422	438	396	189
4	418	442	403	191
5	398	412	371	190
6	383	402	333	191
7	375	396	340	191
8	388	408	349	191

Name: Subject #4 **Date: 5/16/95** **Temp.: 20C** **Warm - up:**

Test # 1(Caffeine) **Time: 2:00pm** **Res.: 3.55kg** **Time: 10min**
Res.: 2.2kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	383	421	347	180
2	349	403	307	184
3	309	370	271	182
4	306	331	283	186
5	299	345	269	185
6	311	327	301	189
7	291	325	262	186
8	317	339	293	193

Name: Subject #4 | **Date: 5-18-95** | **Temp.: 22C** | **Warm - up:**

Test # 2(Placebo) | **Time: 2:00pm** | **Res.: 3.55kg** | **Time:15min Res.: 1.5kg**

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	346	372	330	174
2	365	410	339	184
3	350	402	301	185
4	338	396	295	186
5	314	360	281	185
6	311	353	282	185
7	313	347	293	188
8	321	372	295	191

Name: Subject #5	Date: 6-14-95	Temp.: 21C, 47%	Warm - up:
Test # 1(Placebo)	Time: 7:30pm	Res.: 2.88	Time: 8min Res.: 1.5kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	343	376	329	181
2	338	358	284	184
3	327	361	310	180
4	317	334	303	180
5	313	331	303	180
6	308	323	293	179
7	315	327	304	181
8	310	322	300	177

Name: Subject #5	Date: 6-16-95	Temp.: 21C, 47%	Warm - up:
Test # 2(Caffeine)	Time: 7:40pm	Res.: 2.88	Time: 10min Res.: 0-2.5kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	338	359	320	171
2	344	360	333	183
3	340	367	329	184
4	327	341	315	183
5	327	349	310	184
6	316	325	310	183
7	310	317	297	182
8	322	330	314	184

Name: Subject #6	Date: 6-14-95	Temp.: 21C, 52%	Warm - up:
Test # 1(Placebo)	Time: 6:00pm	Res.: 3.82kg	Time: 10min Res.: 0

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	350	365	337	161
2	359	380	334	169
3	366	425	342	174
4	359	415	319	176
5	336	385	285	176
6	333	375	285	175
7	326	380	301	175
8	338	384	314	176

Name: Subject #6	Date: 6-16-95	Temp.: 21C, 42%	Warm - up:
Test # 2(Caffeine)	Time: 4:00pm	Res.: 3.82kg	Time: 10min Res.: 0

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	349	372	339	165
2	364	393	347	172
3	370	397	350	178
4	352	404	317	180
5	328	384	289	178
6	322	373	289	178
7	320	388	278	178
8	328	400	289	179

Name: Subject #7 **Date: 6-13-95** **Temp.: 22C, 43%** **Warm - up:**

Test # 1(Placebo) **Time: 5 :30pm** **Res.: 3.58kg** **Time: 15min**
Res.: 1.5-2.5

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	407	468	354	185
2	388	455	322	192
3	360	384	317	194
4	350	363	299	194
5	322	351	279	191
6	298	312	279	187
7	285	306	270	186
8	295	326	244	188

Name: Subject #7	Date: 6-15-95	Temp.: 21C, 39%	Warm - up:
Test # 2(Caffeine)	Time: 5 :30pm	Res.: 3.58kg	Time: 12min Res.: 1.5-3.5

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	386	408	370	187
2	366	375	340	189
3	372	389	339	192
4	354	368	315	191
5	354	370	309	193
6	349	361	297	193
7	352	384	281	193
8	352	382	284	194

Name: Subject #8 **Date: 6-28-95** **Temp.: 24C, 59%** **Warm - up:**

Test # 1(Placebo) **Time: 2:30pm** **Res.: 3.64kg** **Time: 15**
Res.: 2-2.5

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	371	400	331	156
2	378	395	306	161
3	377	388	355	166
4	362	375	317	168
5	360	372	320	170
6	353	368	329	170
7	356	377	289	172
8	366	414	314	176

Name: Subject #8	Date: 6/30/1995	Temp.: 23C 58%	Warm - up:
Test # 2(Caffeine)	Time: 2:30pm	Res.: 3.64kg	Time: 10 Res.: 1-3kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	407	421	391	158
2	409	422	377	168
3	392	411	343	172
4	387	402	352	174
5	379	398	359	176
6	369	383	323	176
7	362	386	341	177
8	375	398	320	180

Name: Subject #9	Date: 7-28-95	Temp.: 23 C, 66%	Warm - up:
Test # 1(Caffeine)	Time: 10:40am	Res.: 3.47kg	Time: 15 Res.: 1.25

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	438	470	418	171
2	407	428	348	178
3	384	409	330	177
4	383	412	327	180
5	368	403	342	179
6	378	397	345	182
7	368	403	344	180
8	385	488	328	184

Name: Subject #9 **Date:8-1-95** **Temp.: 24 C, 65%** **Warm - up:**

Test # 2(Placebo) **Time: 9:00am** **Res.: 3.47kg** **Time: 20**
Res.: 1kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	408	451	399	167
2	411	434	403	175
3	395	405	379	174
4	390	416	383	175
5	377	405	357	175
6	370	376	359	173
7	368	398	342	174
8	366	418	331	175

Name: Subject #10 **Date: 7-28-95** **Temp.: 22 C, 67%** **Warm - up:**

Test # 1(Caffeine) **Time: 9:00am** **Res.: 4.2kg** **Time: 10**
Res.: 1-2.5kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	445	509	394	166
2	393	431	354	167
3	366	393	351	167
4	359	416	308	167
5	357	387	317	168
6	364	420	337	170
7	377	430	335	173
8	395	491	332	178

Name: Subject #10 **Date: 7-31-95** **Temp.: 25 C, 41%** **Warm - up:**

Test # 2(Placebo) **Time: 9:00am** **Res.: 4.2kg** **Time: 9min.**
Res.: 1.5kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	430	529	371	161
2	389	473	343	165
3	378	440	348	166
4	370	429	320	166
5	375	431	331	168
6	374	437	321	168
7	372	435	322	169
8	407	490	344	178

Name: Subject #11	Date: 4/25/1995	Temp: 20	Warm - up:
Test # 1(caffeine)	Time: 7:15pm	Res.: 4.14kg	Time: 8min Res.: 1.5kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	427	497	336	176
2	369	503	306	174
3	346	478	279	172
4	345	442	302	173
5	342	449	291	174
6	355	450	315	180
7	337	427	311	176
8	362	441	306	180

Name: Subject #11	Date: 4/27/1995	Temp: 21	Warm - up:
Test # 2(Placebo)	Time: 7:15pm	Res.: 4.14kg	Time: 5min Res.: 1.0kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	387	457	306	159
2	366	479	316	162
3	363	443	310	167
4	359	439	306	170
5	363	468	311	173
6	318	406	275	168
7	355	432	291	177
8	346	493	291	178

Name: Subject #12	Date: 4/25/95	Temp.: 20 C	Warm - up:
Test # 1(Caffeine)	Time: 2:00pm	Res.: 4.18kg	Time: 10 Res.: 2kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	485	504	473	166
2	466	476	457	170
3	445	469	426	168
4	431	446	415	170
5	412	436	383	169
6	398	414	378	167
7	387	406	365	168
8	421	454	404	173

Name: Subject #12	Date: 4/27/95	Temp.: 20 C	Warm - up:
Test # 2(Placebo)	Time: 2:00pm	Res.: 4.18kg	Time: 15 Res.: 2kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	460	474	449	158
2	453	462	439	161
3	442	469	429	164
4	440	462	432	165
5	430	449	418	166
6	411	438	401	163
7	420	436	415	168
8	443	547	416	169

Name: Subject #13	Date: 8-10-95	Temp.: 22 C; 55%	Warm - up:
Test # 1(Caffeine)	Time: 6pm	Res.: 3.93	Time: 10 Res.: 1-1.5

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	420	498	342	171
2	368	427	313	178
3	348	403	311	180
4	336	388	281	180
5	331	370	306	182
6	348	379	328	186
7	338	378	319	184
8	344	390	321	187

Name: Subject #13 **Date: 8-14-95** **Temp.: 28 C; 38%** **Warm - up:**

Test # 2(Placebo) **Time: 6pm** **Res.: 3.93** **Time: 8**
Res.: 1-1.7

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	366	374	356	166
2	368	380	351	170
3	356	371	342	173
4	343	360	321	174
5	326	344	305	172
6	340	360	332	177
7	346	361	332	179
8	347	397	332	181

Name: Subject #14 **Date: 8-18-95** **Temp.: 24 C; 35%** **Warm - up:**

Test # 1(Placebo) **Time: 6pm** **Res.: 2.98** **Time: 15**
Res.: 1.5

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	322	338	292	181
2	325	335	317	187
3	318	330	287	189
4	310	316	284	188
5	312	323	283	189
6	301	315	286	185
7	303	326	281	189
8	303	325	281	188

Name: Subject #14 **Date: 8-21-95** **Temp.: 24 C; 58% Warm - up:**

Test # 2(Caffeine) **Time: 6pm** **Res.: 2.98** **Time: 15**
Res.: 1.5

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	328	346	296	181
2	336	389	312	188
3	346	369	314	190
4	319	331	299	188
5	319	335	298	189
6	325	344	284	193
7	318	328	305	191
8	320	333	299	193

Name: Subject #15	Date: 8-17-95	Temp.: 22 C; 44%	Warm - up:
Test # 1(Caffeine)	Time: 6:45pm	Res.: 3.64kg	Time: Res.:

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	371	380	348	160
2	402	413	389	167
3	395	425	367	168
4	366	392	356	164
5	371	386	360	166
6	379	395	368	169
7	388	418	366	169
8	380	413	365	169

Name: Subject #15 **Date:** 8-21-95 **Temp.:** 24 C; 58% **Warm - up:**

Test # 2(Placebo) **Time:** 6:45pm **Res.:** 3.64kg **Time:** 15 **Res.:** 1-2kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	383	390	375	162
2	394	413	371	164
3	386	419	366	166
4	378	408	366	166
5	373	402	362	163
6	371	405	361	167
7	370	396	357	166
8	377	392	368	168

Name: Subject #16	Date: 8-24-95	Temp.: 22C; 54%	Warm - up:
Test # 1(Placebo)	Time: 6pm	Res.: 3.54	Time: 15 Res.: 0-2.5

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	386	430	339	159
2	392	415	384	160
3	381	390	358	163
4	370	400	352	164
5	354	379	329	163
6	363	379	348	160
7	361	374	332	164
8	374	386	334	168

Name: Subject #16	Date: 8-28-95	Temp.: 22; 50%	Warm - up:
Test # 2(Caffeine)	Time: 6pm	Res.: 3.54	Time: 15 Res.: 0-2kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	395	414	300	162
2	401	417	391	166
3	391	422	370	167
4	374	390	362	167
5	370	394	353	167
6	370	397	354	167
7	365	387	352	170
8	374	406	360	171

Name:	**Subject #17**	**Date: 8-24-95**	**Temp.: 22C; 55%**	**Warm - up:**
Test #	**1(Placebo)**	**Time: 6:45pm**	**Res.: 3.88**	**Time: 15 Res.: 0-2.25**

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	441	480	394	182
2	441	465	352	179
3	379	409	343	182
4	367	397	351	184
5	369	395	346	186
6	372	403	349	188
7	363	393	344	190
8	375	412	346	192

Name: Subject #17	**Date: 8-28-95**	**Temp.: 22; 54%**	**Warm - up:**
Test # 2(Caffeine)	**Time: 6:45pm**	**Res.: 3.88kg**	**Time: 15** **Res.: 0-2.25**

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	432	476	389	181
2	414	443	362	185
3	391	448	345	184
4	381	446	338	185
5	376	434	327	186
6	370	429	327	193
7	364	430	313	175
8	364	429	324	190

Name:	**Subject #18**	**Date: 8-25-95**	**Temp.: 21C; 64%**	**Warm - up:**
Test #	**1(Placebo)**	**Time: 12:45**	**Res.: 3.35**	**Time: 15 Res.: 0-3.5**

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	324	345	313	174
2	323	354	312	176
3	314	341	300	177
4	305	328	294	178
5	301	327	283	178
6	298	332	277	178
7	298	324	255	178
8	308	348	287	179

Name: Subject #18	Date: 8-28-95	Temp.: 22; 43%	Warm - up:
Test # 2(Caffeine)	Time: 2:30pm	Res.: 3.35kg	Time: 15 Res.: 0-3kg

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	329	344	318	182
2	325	339	316	183
3	321	340	309	186
4	311	329	294	186
5	301	334	281	185
6	290	324	249	184
7	298	315	285	184
8	310	334	289	188

Name: Subject #19 **Date: 8-25-95** **Temp.: 21C; 50%** **Warm - up:**

Test # 1(Placebo) **Time: 12pm** **Res.: 3.67** **Time: 15**
Res.: 0-2

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	297	393	108	171
2	289	375	138	174
3	287	373	106	176
4	288	373	97	176
5	264	361	118	176
6	260	355	110	178
7	260	354	116	179
8	282	363	98	183

Name: Subject #19	**Date: 8-27-95**	**Temp.: 21; 57%**	**Warm - up:**
Test # 2(Caffeine)	**Time: 12pm**	**Res.: 3.67kg**	**Time: 10** **Res.: 2-2.5**

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	357	428	343	172
2	349	369	336	174
3	350	373	338	178
4	346	362	333	178
5	332	345	323	177
6	330	344	322	179
7	328	342	319	180
8	348	382	336	184

Name:	**Subject #20	Date: 4/10/95	Temp.: 15 C	Warm - up:
Test #	1(Caffeine)	Time: 7:30am	Res.: 3.44kg	Time: 15 Res.: 1.5-2

Trial #	Mean Power	Maximum power	Minimum Power	Heart Rate
1	312	332	299	171
2	317	346	299	178
3	312	328	290	179
4	307	327	293	181
5	308	380	347	183
6	304	331	287	178
7	295	329	252	181
8	303	344	271	183

**This subject's data not used.

Name:	****Subject #20**	**Date: 4/14/95**	**Temp.: 20.5 C**	**Warm - up:**
Test #	**2(Placebo)**	**Time: 8:00am**	**3.44kg**	**Time: 15 Res.: 1.5**
Trial #	**Mean Power**	**Maximum power**	**Minimum Power**	**Heart Rate**
1	291	311	280	162
2	298	316	289	168
3	300	320	287	170
4	302	320	290	171
5	311	327	289	173
6	321	342	305	178
7	335	349	317	183
8	322	355	295	182

**This subject's data not used.