THE EFFECT OF CAFFEINE ON PEAK TORQUE AND MUSCLE ENDURANCE IN THE KNEE EXTENSORS AND FLEXORS

By

MICKEY DALE WEBER

Bachelor of Science in Arts and Sciences

Oklahoma State University

Stillwater, Oklahoma

1985

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1990

THE EFFECT OF CAFFEINE ON PEAK TORQUE AND MUSCLE ENDURANCE IN THE KNEE EXTENSORS AND FLEXORS

Thesis Approved:

Thesis Adviser

Dean of the Graduate College

ACKNOWLEDGMENTS

I wish to express my appreciation to my major adviser, Dr. Bert H. Jacobson, for his guidance and encouragement throughout this investigation and my graduate program; I could not have accomplished it without his help. Thanks, Bert. Appreciation is also expressed to my other committee members, Dr. Steven W. Edwards and Dr. Frank Kulling, for serving on my graduate committee. Special thanks are offered to Dr. Edwards for his invaluable assistance during the statistical analysis and the preparation of the final manuscript.

A note of thanks is given to the very cooperative men who served as subjects for this study. Without their involvement, the study would not have been possible. Thanks also to Marylin Massey and Terry Saul for their time and valuable assistance during the actual data collection.

Special recognition, deep gratitude, and much love is extended to Debby and Megan for their encouragement and understanding during the long hours spent in research and preparation for this thesis.

Finally, special gratitude and love is expressed to my parents for their patience and encouragement throughout my life and especially during my academic years. I dedicate this project to you--thanks, Mom and Dad.

TABLE OF CONTENTS

LIST OF TABLES

FIGURE

CHAPTER I

INTRODUCTION TO THE PROBLEM

One of three Americans consumes approximately 200 mg of caffeine per day (Leonard, Watson, and Mohs, 1987). Caffeine is an alkaloid structurally identified as xanthine derivative 1,3,7-Trimethylxanthine (Bond et al., 1986; Leonard, Watson, and Mohs, 1987). It belongs to a group of trimethylated xanthines that includes the closely related compounds of theobromine (cocoa) and theophylline (tea) (Leonard, Watson, and Mohs, 1978). The most common sources of caffeine include coffee, tea, chocolate, and cola (Graham, 1978) (Tables I and II). Caffeine is also found in prescription and nonprescription medications, which can substantially add to the level of intake (Leonard, Watson, and Mohs, 1987) (Table III). Of the dietary sources of caffeine, coffee is by far the most important source, accounting for about 75% of America's total caffeine consumption.

Ingested caffeine is rapidly absorbed by the gastrointestinal tract and within minutes is distributed to all tissues and organs (Graham, 1978; Leonard, Watson, and Mohs, 1987). Absorbed caffeine is distributed throughout the body in proportion to tissue water content. Thus, the highest concentration will be found in skeletal muscle (Leonard, Watson, and Mohs, 1987; Williams, Barnes, and Gadberry, 1987). Peak plasma levels for caffeine are reached within 30 to 60 minutes after ingestion, depending on the source and the dose (Leonard, Watson, and Mohs, 1987; Partin, 1988; Stamford, 1989; Weir et al., 1987), but there are large interindividual differences. Robertson et al. (1981) found individual

TABLE I

CAFFEINE CONTENT OF BEVERAGES AND FOODS

Item	Milligrams Caffeine Average	Range
Coffee (5 ounces)		
Brewed, drip method	115	60-180
Brewed, perculator	80	40-170
Instant	65	30-120
Decaffeinated, brewed	3	2-5
Decaffeinated, instant	2	1-5
Tea (5 ounces)		
Brewed, major U.S. brands	40	20-90
Brewed, imported brands	60	25-110
Instant	30	25-50
Iced (12 ounces)	70	67-76
Cocoa beverages (5 ounces)	4	2-20
Chocolate milk beverage (8 ounces)	5	2-7
Milk chocolate (1 ounce)	6	1-15
Dark chocolate, semi-sweet (1 ounce)	20	5-35
Baker's chocolate (1 ounce)	26	26
Chocolate-flavored syrup (1 ounce)	4	4

Source: FDA Consumer, Caffeine Studies Urged, 1981.

TABLE II

CAFFEINE CONTENT OF SOFT DRINKS

Brand	Milligrams Caffeine (12 ounce servings)
Sugar-Free Mr. Pibb	58.8
Mountain Dew	54.0
Mello Yello	52.8
TAB	46.8
Coca-Cola	45.6
Diet Coke	45.6
Shasta Cola	44.4
Shasta Cherry Cola	44.4
Mr. Pibb	40.8
Dr. Pepper	39.6
Sugar-Free Dr. Pepper	39.6
Big Red	38.4
Sugar-Free Big Red	38.4
Pepsi-Cola	38.4
Aspen	36.0
Diet Pepsi	36.0
Pepsi Light	36.0
RC Cola	36.0
Diet Rite	36.0
Kick	31.2
Canada Dry Jamaica Cola	30.0
Canada Dry Diet Cola	1.2

Source: Institute of Food Technologist (IFT), April, 1983.

Note: IFT also reported that there are at least 68 flavors and varieties of soft drinks produced by 12 leading bottlers that have no caffeine.

TABLE III

CAFFEINE CONTENT OF PRESCRIPTION AND NONPRESCRIPTION DRUGS

Drug	Milligrams Caffeine
Prescription Drugs	
Cafergot (for migraine headaches)	100.0
Fiorinal (for tension headaches)	40.0
Soma Compound (pain relief, muscle relaxant)	32.0
Darvon Compound (pain relief)	32.4
Nonprescription Drugs	
Codexin	n/a
Dexa-Diet II	200.0
Dexatrim, Dexatrim Extra Strength	200.0
Dietac Capsules	200.0
Maximum Strength Appendrine	100.0
Prolamine	140.0
Alertness Tablets	
Nodoz	100.0
Vivarin	200.0
Analgesic/Pain Relief	
Anacin, Maximum Strength Anacin	32.0
Excedrin	65.0
Midol	32.4
Vanquish	33.0
Diuretics	
Aqua-Ban	100.0
Maximum Strength Aqua-Ban Plus	200.0
Permathene H2 Off	200.0
Cold/Allergy Remedies	
Coryban-D Capsules	30.0
Triaminin Tablets	30.0
Dristan Decongestant Tablets and Dristan A-F Decongestant Tablets	16.2
Duradyne-Forte	30.0

Source: Federal Drug Administration (FDA), National Center for Drugs and Biologics, 1983.

to vary from 15 to 120 minutes for caffeine to reach peak plasma levels. The reasons for the interindividual differences in peak plasma levels among the subjects were unknown.

The metabolic half-life of caffeine in the plasma and most organs varies among individuals and ranges from 3 to 13 hours (Fisher et al., 1986; Graham, 1978; Leonard, Watson, and Mohs, 1987; Stamford, 1989). The usual pharmacologically active dose of caffeine is 200 mg and is used medicinally for a variety of purposes (Table IV). Lethal doses in adults occur in a range from 3 to 10 grams, depending on individual lean body weight (Leonard, Watson, and Mohs, 1987).

TABLE IV

PHARMACOLOGICAL USES OF CAFFEINE AND RELATED COMPOUNDS

Desired Action	Preferred Compound
Cerebral Stimulation	Caffeine (coffee)
Coronary Dilation	Theophylline (tea)
Diuresis	Theobromine (cocoa)
Respiratory Stimulant for Premature Infants	Caffeine

Source: D. M. Graham, "Caffeine--Its Identity, Dietary Sources, Intake and Biological Effects," Nutrition Reviews (1978).

Caffeine is recognized as a stimulant by the International Olympic Committee, which limits its use, allowing up to 15 $mg.ml^{-1}$ in the urine (Marcus, 1986). This is the equivalent of 6-8 cups of coffee consumed within two to three hours (Rothstein et al., 1983). Although caffeine is recognized as a stimulant, tolerance to caffeine by habitual consumption may alter the response, both at rest and during exercise (Colton, Gosselin, and Smith, 1968). Furthermore, four days or more of withdrawal from caffeine resensitizes an individual to caffeine's physiological effects (Fisher et al., 1986). Fisher et al. pointed out that caffeine habits of individuals must be controlled to gather precise data on the effect of caffeine.

Statement of the Problem

The interest and use of caffeine as an ergogenic aid has stimulated numerous researchers to investigate the effects of caffeine on many physiological parameters associated with various types of exercise (Butts and Crowell, 1985). One individual reported consuming the equivalent of 41 cups of coffee prior to competition for the purpose of gaining an "extra edge" with respect to performance (Bosworth and Reilly, 1988). Caffeine has been associated with the enhancement of aerobic endurance (Butts and Crowell, 1985; Costel, Datsky, and Fink, 1978; McNaughton, 1986) and speed of movement (Jacobson and Edgley, 1987). Presently, only five studies known to the researcher have investigated the effects of caffeine on human skeletal muscle contractile properties in vivo (Bond et al., 1986; Bugyi, 1980; Jacobson, 1989; Lopes et al., 1983; Williams et al., 1988). These studies have shown no measurable effect on voluntary strength or power using moderate (300 mg) to high (800 mg) caffeine ingestions.

The problem of this study was to investigate the effects of caffeine ingestion on peak torque and muscle endurance in man during low, moderate, and high speeds of contraction. The subjects were: (1) highly resistance trained, (2) given dietary guidelines to follow previous to testing (Weir et al., 1987), and (3) given large doses of caffeine (7 mg/kg/bwt), as suggested by Bond et al. (1986), Bugyi (1980), and Jacobson (1989).

Hypotheses

The specific hypotheses tested were of caffeine ingestion upon peak torque and muscle endurance, as indicated by limb movement. This study attempted to determine if a high caffeine dose affected musculoskeletal strength and endurance. The following hypotheses were tested:

HO_1: There is no significant difference between the control group and the experimental group in extension peak torque at an angular velocity of 30 degrees per second.

HO_2: There is no significant difference between the control group and the experimental group in extension peak torque at an angular velocity of 150 degrees per second.

HO_3: There is no significant difference between the control group and the experimental group in extension peak torque at an angular velocity of 300 degrees per second.

HO_4: There is no significant difference between the control group and the experimental group in extension peak torque at 30 degrees in ROM at an angular velocity of 30 degrees per second.

HO_5: There is no significant difference between the control group and the experimental group in extension peak torque at 30 degrees in ROM at an angular velocity of 150 degrees per second.

HO_6: There is no significant difference between the control group and the experimental group in extension peak torque at 30 degrees in ROM at an angular velocity of 300 degrees per second.

HO_7: There is no significant difference between the control group and the experimental group in extension peak torque at 70 degrees in ROM at an angular velocity of 30 degrees per second.

HO_8: There is no significant difference between the control group and the experimental group in extension peak torque at 70 degrees in ROM at an angular velocity of 150 degrees per second.

HO_9: There is no significant difference between the control group and the experimental group in extension peak torque at 70 degrees in ROM at an angular velocity of 300 degrees per second.

HO_{10}: There is no significant difference between the control group and the experimental group in flexion peak torque at an angular velocity of 30 degrees per second.

HO_{11}: There is no significant difference between the control group and the experimental group in flexion peak torque at an angular velocity of 150 degrees per second.

HO_{12}: There is no significant difference between the control group and the experimental group in flexion peak torque at an angular velocity of 300 degrees per second.

HO_{13}: There is no significant difference between the control group and the experimental group in flexion peak torque at 30 degrees in ROM at an angular velocity of 30 degrees per second.

HO_{14}: There is no significant difference between the control group and the experimental group in flexion peak torque at 30 degrees in ROM at an angular velocity of 150 degrees per second.

HO_{15}: There is no significant difference between the control group and the experimental group in flexion peak torque at 30 degrees in ROM at an angular velocity of 300 degrees per second.

HO_{16}: There is no significant difference between the control group and the experimental group in flexion peak torque at 70 degrees in ROM at an angular velocity of 30 degrees per second.

HO_{17}: There is no significant difference between the control group and the experimental group in flexion peak torque at 70 degrees in ROM at an angular velocity of 150 degrees per second.

HO_{18}: There is no significant difference between the control group and the experimental group in flexion peak torque at 70 degrees in ROM at an angular velocity of 300 degrees per second.

HO_{19}: There is no significant difference between the control group and the experimental group in extension torque accelerated energy at an angular velocity of 300 degrees per second.

HO_{20}: There is no significant difference between the control group and the experimental group in flexion torque accelerated energy at an angular velocity of 300 degrees per second.

HO_{21}: There is no significant difference between the control group and the experimental group in extension torque first three repetitions at an angular velocity of 300 degrees per second.

HO_{22}: There is no significant difference between the control group and the experimental group in flexion torque first three repetitions at an angular velocity of 300 degrees per second.

HO_{23}: There is no significant difference between the control group and the experimental group in extension torque last three repetitions at an angular velocity of 300 degrees per second.

HO_{24}: There is no significant difference between the control group and the experimental group in flexion torque last three repetitions at an angular velocity of 300 degrees per second.

HO_{25}: There is no significant difference between the control group and the experimental group in extension endurance ratio at an angular velocity of 300 degrees per second.

HO_{26}: There is no significant difference between the control group and the experimental group in flexion endurance ratio at an angular velocity of 300 degrees per second.

HO_{27}: There is no significant difference between the control group and the experimental group in extension total watts at an angular velocity of 300 degrees per second.

HO_{28}: There is no significant difference between the control group and the experimental group in flexion total watts at an angular velocity of 300 degrees per second.

Delimitations

The following were the delimitations of this study:

1. The total number of subjects volunteering for the study was 20.

2. The testing was administered at the Oklahoma State University Sports Medicine Department because of the location of the Cybex II Computer.

3. There was only one dosage administered to the subjects (7 mg/kg/bwt).

4. All subjects were highly resistance trained Division I football players.

Limitations

This study was subject to the following limitations:

1. The test subjects were asked to follow a restricted diet consisting of the following:

   a. High carbohydrate foods were restricted two days prior to the testing.

   b. Caffeine ingestion of any form was restricted for four days prior to testing.

   c. The subjects were told to arrive at the test on Monday morning with an empty stomach (i.e., no breakfast) following an overnight fast of 8-10 hours.

2. All subjects were tested on the right side without considering a dominant side choice.

3. All subjects were asked to abstain from strenuous exercise for 48 hours before testing.

Assumptions

For the purposes of this study, the following assumptions were accepted by the researcher:

1. Subjects correctly followed all instructions.

2. Subjects correctly followed the dietary restrictions.

3. Subjects received 7 mg/kg/bwt of caffeine prior to testing.

4. Subjects abstained from strenuous exercise 48 hours before testing.

Definitions

The following are terms used in this study:

E = Extension

F = Flexion

3 = 30 degrees/second velocity

15 = 150 degrees/second velocity

30 = 300 degrees/second velocity

TQ = Torque

30 = 30 degrees in range of motion

70 = 70 degrees in range of motion

TA = Torque Acceleration Energy

F3 = First 3 reps

L3 = Last 3 reps

ER = Endurance Ratio

WT = Watts

ROM = Range of Motion

CHAPTER II

LITERATURE REVIEW

Introduction

Athletes at all levels of competition are continually looking for a means of gaining the competitive edge over their rivals. Caffeine, in recent years, has been the current topic of study as an ergogenic aid. An ergogenic aid can be defined as anything that may enhance work or the potential for work output. The assumption that caffeine will act as an ergogenic agent to aid physiological work output is based on the following: (1) its glycogen sparing effect on exercise metabolism (Butts and Crowell, 1985; Partin, 1988; Weber, 1968), (2) its stimulatory effects on the CNS (Ivy et al., 1979), and (3) its direct action on the skeletal muscle contractile mechanism (Leonard, Watson, and Mohs, 1987; Partin, 1988; Weber, 1968).

Caffeine and Endurance

Caffeine has been shown to enhance endurance performance activities (Butts and Crowell, 1985; Colton, Gosselin, and Smith, 1968; Erickson, Schwarzkopf, and McKenzie, 1987; Fisher et al., 1986; Ivy et al., 1979; McNaughton, 1986; Partin, 1988; Weir et al., 1987). Caffeine triggers normal production of epinephrine, elevating the release of free fatty acids (FFA) into the blood (Marcus, 1986). The uptake of FFA by working muscles appears to be related to how much FFA is in the blood (Fox,

1984). Available FFA is preferentially used as a fuel source during exercise, eliciting between 60% and 85% VO_2 max, where the duration of exercise approaches or exceeds one hour (Costill, Datsky, and Fink, 1978). The primary reason for prolonged aerobic endurance enhancement would appear to be increased fat utilization leading to a glycogen sparring effect (Fisher et al., 1986). McNaughton (1986) found that the increase in running time to exhaustion was influenced by the amount of caffeine ingested. Fox (1984) stated that the primary energy sources during one hour of cycling are triglycerides (32%) and glycogen (44%) stored within the muscle itself. Caffeine's induced response as an energy source will effect the amount of stored glycogen used by increasing FFA within the blood, thus causing a shift in substrate utilization.

With the ingestion of 330 mg of caffeine, Costill, Datsky, and Fink (1978) demonstrated a 50% to 100% increase in plasma FFA during cycling to exhaustion at 80% VO_2 max, resulting in an increased endurance time prior to exhaustion. Peak FFA response to caffeine usually occurs three to four hours after caffeine ingestion. Thus, if the activity depends on caffeine's lipid-mobilizing effect, exercise should be done three to four hours after ingestion (Weir et al., 1987).

Central Nervous System Effects

Caffeine's popularity is due, in part, to its stimulatory effects on the central nervous system (CNS). Following caffeine ingestion, the CNS is first affected in the cortex of the brain, then the medulla, and, with large amounts, the spinal cord (Leonard, Watson, and Mohs, 1987). The stimulatory effects of caffeine depend on the source and the dose (Weir et al., 1987). Caffeine may enhance neuromuscular transmission and increase neuronal excitability by reducing motor neuronal firing thresholds

(Costill, Datsky, and Fink, 1978; Williams, Barnes, and Gadberry, 1987). In a study by Williams, Barnes, and Gadberry (1987), caffeine ingestion (7 mg/kg/bwt) did not alter motor unit recruitment patterns or the shape of the action potential waveform as detected from the frequency spectral analysis of electromyograms.

Caffeine and Skeletal Muscle Contractility

Caffeine has been shown to have a direct effect on skeletal muscle contractility (Lopes et al., 1983; Weber, 1968; Williams, Barnes, and Gadberry, 1987). Lopes et al. (1983) demonstrated that for low frequencies of stimulation, the tension developed was higher after caffeine ingestion, suggesting a direct effect on muscle contraction. The sarcoplasmic reticulum (SR), a membranous structure that surrounds each muscle fiber, controls the contractile activity of muscle fibers by regulating calcium levels within the myofilament space (Wood, 1978). It has been demonstrated that the actual site of calcium release in the SR is the terminal cisternae (Bianchi and Narayan, 1982; Frank, 1986). The transverse tubular element acts as a conduit for the muscle action potential to the fiber interior (Bianchi and Narayan, 1982). Bianchi and Narayan (1982) suggested that the T-tubular element also has a major role in removing calcium that is released from the terminal cisternae. Nassar-Gentina, Passonneau, and Rapoport (1981) found that the uncoupling in fatigued fibers was a functional discontinuity between the transverse tubular element and the SR and feels this can be reversed by caffeine induced release of calcium from intercellular stores. Caffeine causes an increase in cellular calcium through an increased permeability (decreased uptake) of the terminal cisternae to calcium (Chuck and Parmley, 1980; Lopes et al., 1983; McNaughton, 1986), and/or an increase in the release

of calcium from the terminal cisternae of the SR (Butts and Crowell, 1985; Fisher et al., 1986; Weber, 1968). Weber (1968) and Axelsson and Thesleff (1958) have shown caffeine induced contracture to be independent of neuronal depolarization.

Caffeine and Muscular Strength

Caffeine appears to have no beneficial effect on short-term anaerobic exercise (Bond et al., 1986; Bugyi, 1980; Partin, 1988; Williams, Barnes, and Gadberry, 1987; Williams et al., 1988). Gaesser and Rich (1985) suggested that low doses (5 mg/kg/bwt) may not raise FFA to a level where it alters substrate utilization during short-term incremental work. Lopes et al. (1983) studied the effects of an oral administration of 500 mg of caffeine on voluntary isometric and electrically stimulated contractions of the adductor pollicis muscle in five adults. The data showed that caffeine produced an increase in the tension developed in the muscle at all stimulation frequencies lower than 100 Hz, suggesting a direct effect on muscle contraction. Tension developed during low levels of stimulation and not at the higher level of stimulation.

Bugyi (1980) found no statistical difference between initial and final strength using a hand grip test as a result of the ingestion of 170-500 mg caffeine, but noticed a slight trend of increased strength in the higher dose (500 mg) group. Williams et al. (1988) found caffeine to produce no significance in EMb tracings during submaximal and maximal contractions when compared with the control. Williams et al. concluded that (7 mg/kg) showed no difference in isometric force or muscle endurance.

Bond et al. (1986) studied the effect of (5 mg/kg) ingestion of caffeine on isokenetic strength in 12 male intercollegiate sprinters.

The subjects ingested caffeine, or a placebo, followed by a 60-minute absorption period. The subjects were then tested using a Dual Channel Cybex II Isokinetic Dynamometer connected to a Cybex II Data Reduction computer. Knee flexion and extension of the right leg were tested at the selected angular velocities of 30, 150, and 300 degrees. Bond et al. (1986) concluded that caffeine in small doses exerts no influence on muscle function at low, moderate, and high contracting velocities tested in vivo. Jacobson (1989), in a study similar to Bond et al. (1986), used the angular velocities of 75, 180, and 300 degrees per second. Using 300 mg and 600 mg caffeine, no difference was shown in isokinetic force or muscular endurance.

Dietary Influences on Caffeine's Effects

When glycogen reserves are increased within the body, utilization of carbohydrates is increased and fat utilization is decreased. Weir et al. (1987) showed that both the nutritional status of the subjects before exercise and the nature of the food ingested with the caffeine significantly influenced the FFA response to caffeine. Caffeine's effects on lipid metabolism are considerably reduced using high carbohydrate diets (Fox, 1984), whereas a low carbohydrate diet will potentiate the metabolic effect of caffeine (Kots, Vinogradova, and Danicheva, 1984). The effects of diet on caffeine and the contractile mechanism during anaerobic work have not been investigated.

CHAPTER III

METHODS

Subjects

Twenty subjects were randomly chosen from the Oklahoma State University varsity football team on a voluntary basis. All subjects were highly trained athletes and were assumed to be capable of eliciting maximal force due to extensive previous training at maximal outputs. All subjects were involved in a thorough physical screening prior to the competitive season and these records were reviewed by the team physician. The following criteria were the basis for elimination in the study: those with a history of any cardiac or vascular disorder, stomach or intestinal disorder, high blood pressure ($\geq$ 140/90 mm/Hg), high resting HR ($\geq$ 110), mental or emotional disorders, currently on medication, or currently ill.

A questionnaire was given to determine caffeine consumption history in the form and quantity of daily and weekly uses of coffee, tea, soft drinks with caffeine, and over-the-counter drugs (Appendix B). Following verbal consent, the subjects agreed to sign an informed consent document, as approved by the regulations specified by the university Institutional Review Board (IRB).

Preliminary Procedures

Prior to testing, the subjects were asked to fast for a minimum of

eight hours prior to the experiment and to avoid any caffeine for four days prior to the onset of the experiment (Erickson, 1987). A list containing common caffeine products to avoid was given to the subjects so that little or no caffeine would be included in their diet for four days prior to testing (Appendix C). To potentiate the metabolic effects of caffeine (Jacobson, 1989; Weir et al., 1987), a low carbohydrate diet was given to each subject. The diet was followed for 48 hours prior to the testing. Additionally, the subjects agreed to abstain from strenuous exercise for 48 hours before testing.

All subjects were briefed as to the procedures and objectives of the investigation prior to the experiment. The tests were conducted in a quiet room to prevent any external interference during the procedure. Each subject was given the same instructions to exert maximal effort during each trial. All motivation and encouragement was done prior to test only.

Procedures

Each of the subjects was given one of two oral capsules, as prepared by a pharmacist. Each subject ingested either anhydrous caffeine (7 mg/kg) or a placebo (225 mg methycellulose) placed in a gelatin capsule. The capsules were individually prepared for each subject according to body weight. All treatments were administered in a double-blind format.

The protocol for this investigation was consistent to that of Bond et al. (1986), in that data for muscular output at selected angular velocities was collected using a Cybex II dynamometer interfaced with a Cybex data reduction computer. Isokinetic testing allows muscular strength and power to be monitored at fixed angular speeds. The velocity may be

selected at predetermined rates as the resistance varies in accordance to the force applied at every point in the joint range of motion (ROM) (Davies, 1984). Isokinetic torque and power was tested at three angular velocities of contraction (30, 150, and 300 degrees per second). In testing the knee extensors and flexors on the Cybex II, the ROM tested was 90 degrees. The knee joint was able to obtain complete knee extension during testing, but was limited during knee flexion due to a pad located on the apparatus. Consequently, the machine tested the last 90 degrees of knee extension and the first 90 degrees of flexion within the ROM of the knee joint.

Six variables were measured at an angular velocity of 30 degrees (Table V): (1) extension peak torque (3ETQ), (2) extension torque at 30 degrees ROM (3E30), (3) extension torque at 70 degrees ROM (3E70), (4) flexion peak torque (3FTQ), (5) flexion torque at 30 degrees ROM (3F30), and (6) flexion torque at 70 degrees ROM (3F70).

In the context of isokinetic testing, strength is defined as any velocity at or below 60 degrees/second (Davies, 1984). A contraction velocity of 30 degrees/second would take three seconds to extend the leg at the knee and three seconds to flex the leg at the knee, since the ROM tested is 90 degrees. The lever arm of the Cybex II measured the amount of force (torque) applied during this time. More torque can be applied at 30 degrees/second than at 150 degrees or 300 degrees/second, due to the slower movement speed (Fleck and Kraemer, 1987).

The perceived movement speed at the lever arm at a fixed speed (i.e., 30 degrees/second) will appear to be the same for each subject, even though the measured strength of the subjects will vary. The Cybex II measures the amount of force produced by each subject at each predetermined velocity.

TABLE V

MEANS AND STANDARD DEVIATIONS FOR ALL TESTS (NEWTON METERS)

Test	Pre-Placebo	Post-Placebo	Pre-Caffeine	Post Caffeine
3ETQ	295±54	284±50	291±58	313±56*
3E30	188±39	194±39	187±43	209±53
3E70	271±58	256±46	279±56	284±49*
3FTQ	200±34	203±34	195±29	206±33
3F30	284±33	185±34	186±35	188±37
3F70	134±26	127±27	134±31	130±27
15ETQ	236±38	237±40	244±36	251±41
15E30	185±34	199±35	203±41	211±38
15E70	198±42	185±31	195±33	196±34
15FTQ	157±27	158±20	158±23	167±27
15F30	148±29	151±29	151±25	159±24
15F70	128±27	122±19	128±22	137±26*
30ETQ	158±27	156±27	155±37	166±33*
30E30	141±25	140±23	140±31	153±34*
30E70	117±34	118±38	108±41	115±31
30FTQ	108±16	120±15	119±18	126±22
30F30	99±18	106±19	100±20	110±27
30F70	98±14	94±14	98±15	999±20
30ETA	6467±1059	6526±1059	6356±1395	6892±1301*
30EF3	448±95	455±83	459±114	490±103
30EL3	389±77	391±86	392±94	403±76
30EER	121±23	117±16	120±33	114±26
30EWT	619±133	595±105	597±143	632±130*
30FTA	4757±877	4913±714	4668±770	5172±947
30FF3	422±67	420±60	420±75	450±88
30FL3	283±61	290±54	286±45	305±67
30FER	92±19	94±14	93±15	94±15
30FWT	461±83	453±68	452±80	478±91

*Tests showing significance at alpha = 0.05

Six dependent variables were measured at an angular velocity of 150 degrees per second (Table V): (1) extension peak torque (15 ETQ), (2) extension torque at 30 degrees ROM (15E30), (3) extension torque at 70 degrees ROM (15E70), (4) flexion torque (15FTQ), (5) flexion torque at 30 degrees ROM (15F30), and (6) flexion torque at 70 degrees ROM (15F70).

Any isokinetic tests utilizing an angular velocity in excess of 60 degrees/second are considered tests of muscular power, thus incorporating time and work (Davies, 1984). A contraction velocity of 150 degrees/second would take 0.6 seconds to extend the leg at the knee and 0.6 seconds to flex the leg at the knee on the Cybex II.

Sixteen variables were measured at an angular velocity of 300 degrees/second (Table V): (1) extension peak torque (30ETQ), (2) extension torque at 30 degrees ROM (30E30), (3) extension torque at 70 degrees ROM (30E70), (4) flexion peak torque (30FTQ), (5) flexion torque at 30 degrees ROM (30F30), (6) flexion torque at 70K ROM (30F70), (7) extension torque accelerated energy (30ETA), (8) flexion torque accelerated energy (30FTA), (9) extension torque first 3 reps (30EF3), (10) flexion torque first 3 reps (30FF3), (11) extension torque last 3 reps (30EL3), (12) flexion torque last 3 reps (30FL3), (13) extension endurance ratio (30EER), (14) flexion endurance ratio (30EER), (15) extension total watts (30EWT), and (16) flexion total watts (30FWT). A contraction velocity of 300 degrees/second would take 0.3 seconds to extend the leg at the knee and 0.3 seconds to flex the leg at the knee.

To avoid interference by fatigue between the tests, 60 seconds were allowed between pre and posttest at each of the two sessions. The lever arm of the Cybex was adjusted to fit four inches above the lateral malleolus for each subject (Stamford, 1989). At pretest, the adjustment

number on the lever arm was recorded for each subject so that the same number could be used in the posttest.

Data Analysis

The subjects were tested at the same time on two consecutive Mondays. Half of the subjects received caffeine on day one and the other half received caffeine on day two. A 2 x 2 repeated measures ANOVA was used to analyze the results (Figure 1). This analysis uses: (1) one grouping factor, Group 1 vs. Group 2 and (2) on trial factor, caffeine vs. no caffeine. An alpha level of .05 was used to determine statistical significance. The Newman-Keals multiple range test for mean comparisons was used for post-hoc analysis.

Groups				
	1	$\overline{X}_{C_1}$	$\overline{X}_{NC_1}$	$\overline{X}_1$
	2	$\overline{X}_{C_2}$	$\overline{X}_{NC_2}$	$\overline{X}_2$
		$\overline{X}_C$	$\overline{X}_{NC}$	

(C) = Caffeine; (NC) = No Caffeine

Treatment (T) = $\overline{X}_C = \overline{X}_{NC}$

Group (G) = $\overline{X}_1 = \overline{X}_2$

G x T = $\overline{X}_{C_1} = \overline{X}_{C_2} = \overline{X}_{NC_1} = \overline{X}_{NC_2}$

Figure 1. A 2 x 2 Repeated Measures ANOVA

Post Procedures

A certified athletic trainer (A.T.C.) was present during the testing to monitor HR and BP at the end of the experiment. Subjects were encouraged to eat immediately after the testing, and then were asked how they felt. Any subject who indicated ill feelings would be taken to the University Health Center. No such cases appeared.

CHAPTER IV

RESULTS AND DISCUSSION

Characteristics of Subjects

Twenty varsity division I college football players participated in this study. The average age of the subjects was 21 $\pm$ 1.2 years. The weight of the subjects ranged from 79 kg to 122 kg, with a mean of 101 $\pm$ 15 kg. The height of the subjects was 187 $\pm$ 9 centimeters. The subjects were highly trained in resistance exercise, with 4.9 $\pm$ 1.79 years of participation. Results of the questionnaire (Appendix B) given to each subject to determine training background is presented in Table VI. The mean daily caffeine consumption by the subjects as determined by a caffeine consumption questionnaire (Appendix B) was 72 $\pm$ 56 mg, depending on brand (Appendix C). Coffee was not part of the regular diet of the subjects, and tea was consumed by only two participants. The subjects were tested during the summer strength program, which is the time of year when football players are usually in their best physical condition.

Results at an Angular Velocity of 30%

Statistical analysis indicated a significant difference for extension peak torque and extension peak torque at 70 degrees ROM in in the control group with the ingestion of caffeine (7 mg/kg bwt) (Table VII). Extension torque at 30 degrees ROM was not significant (see Table V, Chapter III). The placebo group showed no difference in any dependent

TABLE VI

CHARACTERISTICS OF SUBJECTS

	Subject Number																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Mean
Age	21	21	21	22	21	21	23	22	23	20	21	23	20	19	19	20	20	21	21	22	21 ± 1.2
Height (cm)	173	178	178	185	185	193	185	191	188	191	195	193	183	175	188	183	191	195	191	195	187 ± 9
Weight (kilos)	83	98	80	104	86	122	94	117	110	113	122	113	87	79	115	83	109	115	90	113	101 ±15
Coffee (cups/day)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Softdrink (can/day)	6	2	0	1	1	2	2	2	3	1	1	3	1	0	1	0	4	2	0	1	1.65 ± 1.45
Tea (cups/day)	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.15 ± 0.47
Resistance Training (years of participation)	4	3	6	6	5	3	8	6	5	4	6	8	6	2	2	6	6	4	2	6	4.9 ± 1.79

variable at 30 degrees/second. Flexion peak torque and flexion torque at 30 degrees and 70 degrees ROM showed no difference in the control group.

TABLE VII

ANOVA TESTS

1.3ETQ

Source	SS	DF	MS	F
CXT	3276.8	1	3276.8	15.29
Error	4071.2	19	214.3	

2.3E70

Source	SS	DF	MS	F
CXT	2332.8	1	2332.8	8.85
Error	5009.7	19	263.7	

3.15F70

Source	SS	DF	MS	F
CXT	248.5	1	248.5	4.96
Error	951.0	19	50.0	

4.30ETQ

Source	SS	DF	MS	F
CXT	540.8	1	540.8	9.09
Error	1130.7	19	59.5	

5.30E30

Source	SS	DF	MS	F
CXT	644.1	1	644.1	8.58
Error	1426.6	19	75.0	

6.3ETA

Source	SS	DF	MS	F
CXT	618816.2	1	618816.2	10.37
Error	113397.8	19	59652.5	

7.30EWT

Source	SS	DF	MS	F
CXT	8946.5	1	8946.5	16.69
Error	10182.1	19	535.9	

At an angular velocity of 30 degrees/second, the 1st and 7th hypotheses were rejected. The 4th, 10, 13th, and 16th hypotheses were accepted.

Results at an Angular Velocity of 150 Degrees/Second

Flexion torque at 70 degrees in ROM resulted in a significant difference with the ingestion of caffeine (7 mg/kg bwt) (Table VII). Extension peak torque, extension torque at 30 degrees in ROM, extension torque at 70 degrees in ROM, flexion peak torque, and flexion torque at 30 degrees ROM indicated no difference. The control (placebo) group showed no significant difference.

At an angular velocity of 150 degrees/second, the 16th hypothesis was rejected. The 2nd, 5th, 8th, 11th, and 14th hypotheses were accepted.

Results at an Angular Velocity of 300 Degrees/Second

Extension peak torque and extension torque at 30 degrees ROM indicated significance with the ingestion of caffeine (7 mg/kg bwt). Torque accelerated energy (TAE) is a measure of the explosiveness of a muscle contraction and is measured by the total work done in the first one eighth of a second (Davies, 1984). Extension TAE significantly increased with caffeine ingestion, indicating an increase in muscle explosive power. Average power, or watts, is defined as the total work divided by the time to perform the work. Extension watts were significantly increased with ingested caffeine (Table VII).

Extension at 70 degrees ROM, flexion peak torque, flexion at 30 degrees and 70 degrees ROM, extension first and last three reps, extension and flexion endurance ratio, flexion torque accelerated energy, flexion first and last three reps, and flexion watts were not significantly

affected by caffeine ingestion. No dependent variable within the control group was significant between tests at 300 degrees/second.

At an angular velocity of 300 degrees/second, the 3rd, 6th, 19th, and 27th hypotheses were rejected. The 9th, 12th, 15th, 18th, 20th, 21st, 22nd, 23rd, 24th, 25th, 26th, 27th, and 285h hypotheses were accepted.

Discussion of Results

Statistical analyses revealed that a high dose of caffeine (7 mg/kg bwt) will enhance some parameters of anaerobic strength and power. This finding does not support the other available research that has been done in this area (Bond et al., 1986; Bugyi, 1980; Partin, 1988; Williams, Barnes, and Gadberry, 1987; Williams, et al., 1988).

Possible explanations for the significant effects of caffeine in this investigation are speculation, but the following may be responsible factors: (1) the subjects were highly resistance trained (Table VI), (2) the amount of caffeine (7 mg/kg bwt) was a larger dosage than most previous related studies, (3) the diet was caffeine restricted (four days) and carbohydrate limited (two days), and (4) the subjects' fiber-type distribution was speculatively higher in type IIa and type IIb fibers and lower in type I.

The amount of caffeine used for each subject in this investigation was higher than previous investigations on short-term anaerobic voluntary strength (Bond et al., 1986; Bugyi, 1980; Nassar-Gentina, Passonneau, and Rapoport, 1981; Weir et al., 1987; Wood, 1987). Most recently, Williams et al. (1988) used the same dosage (7 mg/kg bwt) in an investigation involving voluntary peak power output by using a modified bicycle ergometer and found no significance following caffeine ingestion. Bond

et al. (1986), in a voluntary strength investigation using a similar protocol, found no effect on isokinetic strength with 5 mg/kg bwt. The amount used for this investigation (7 mg/kg bwt) is equivalent to six to eight cups of coffee. Most previous investigations have used an equivalent of three to five cups of coffee (Bond et al., 1986; Bugyi, 1980; Partin, 1988). A dose this high would be hard to obtain using regular consumption habits, but not any higher than the common doses used by athletes.

Brian Bosworth (All-American linebacker at the University of Oklahoma and first round professional draft choice), in his book The Boz (Bosworth and Reilly, 1988) indicated that his use of caffeine before games was as high as 4,100 mg. This would be the equivalent of 41 cups of coffee. Tony Mandrich (cited in Telander, 1989), offensive tackle for the Green Bay Packers, attributed increased performance to similar caffeine dosages. The dose used in this investigation was high enough to be considered illegal by the International Olympic Committee's (IOC) and the National Collegiate Athletic Association's (NCAA) rules, as tested by urinalysis. The IOC allows up to 15 $ug.ml^{-1}$ levels of caffeine before it is considered an illegal substance. In Williams et al. (1988), 7 mg/kg bwt resulted in a mean caffeine plasma concentration of nearly 50 $mg.ml^{-1}$.

The subjects followed a low carbohydrate diet two days prior to testing in order to potentiate the metabolic effects of caffeine (Kots, Vinogradova, and Danicheva, 1984; Weir et al., 1987). The subjects were asked to avoid fruits, potatoes, rice, and pasta noodles during this two-day period (Appendix C). Caffeine's effects on lipid metabolism are considerably reduced using high carbohydrate diets (Fox, 1984). Although this investigation tested anaerobic capacities that require primarily

carbohydrate metabolism, the researchers' intentions were to fully potentiate the effects of the drug itself. Previous studies have not mentioned the use of a controlled diet other than fasting the night before the testing (Bond et al., 1986; Bugyi, 1980; Partin, 1988; Williams, Barnes, and Gadberry, 1987; Williams et al., 1988).

All of the subjects were highly trained in resistance exercise and were familiar with the Cybex II isokinetic dynamometer. Previous investigations did not indicate the use of highly resistance trained subjects (Bond et al., 1986; Bugyi, 1980; Partin, 1988; Williams, Barnes, and Gadberry, 1987; Williams et al., 1988). The subjects in this investigation understood how to elicit a maximal response and had a physiological system that was trained for short-term anaerobic voluntary strength. The physiological system can be specifically trained to perform short-term anaerobic voluntary strength with more efficiency (Frank, 1986; Gaesser and Rich, 1985). Elite anaerobic athletes, like the ones used in this investigation, would have a greater inherent capacity for physiological improvement from specific anaerobic training.

An additional possibility for the strength/caffeine response may have been the subjects' fiber type distribution. The subjects used were elite anaerobic athletes, suggesting a higher than average fast twitch type IIa and IIb fiber distribution. Caffeine's effects on the contractile mechanism may primarily affect elite anaerobic subjects, due to a larger and more efficient sarcoplasmic reticulum (Bianchi and Narayan, 1982; McNaughton, 1986; Weir et al., 1987; Wood, 1978; Williams et al., 1988). Lopes et al. (1983) noted that, in response to caffeine ingestion, type I fibers may react differently from type II fibers and that smaller muscles (hamstrings) may not be affected to the same extent as

larger muscles (quadriceps). If so, caffeine's effects on voluntary anaerobic strength would be more pronounced in elite anaerobic athletes.

Of the seven variables showing significance, only one occurred for knee flexion. The other six variables occurred for knee extension. A possible explanation for this occurrence could be because of the greater muscle mass of the extensors (McNaughton, 1986). Absorbed caffeine is distributed in the body in proportion to tissue water content. The greater the muscle mass, the greater the amount of distributed caffeine.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDY

Summary

Statistical analyses revealed that a high dose of caffeine (7 mg/kg bwt) will enhance some parameters of anaerobic strength and power. This finding does not support the other available research that has been done in this area (Bond et al., 1986; Bugyi, 1980; Partin, 1988; Williams, Barnes, and Gadberry, 1987; Williams et al., 1988). Significance occurred at all three velocities of contraction, indicating a significant increase in strength (30 degrees/second) and power (150 degrees/second, 300 degrees/second) with the ingestion of 7 mg caffeine/kg bwt. Explosive power (TAE) and total work were also significantly increased at a high angular velocity (300 degrees/second). The original hypothesis stating that caffeine ingestion would not significantly affect isokinetic strength was rejected in seven dependent variables and retained in 21 dependent variables (see Table V, Chapter III).

Conclusions

Currently, this is the only investigation to indicate that high doses of caffeine can positively effect some parameters of short-term anaerobic voluntary strength. Additional research with caffeine

ingestion and anaerobic work capacities is needed to substantiate any claims to its ergogenic effects.

Recommendations for Further Study

Future investigations should use elite anaerobic athletes that have the capacity to push themselves in protocols similar to their activities (specificity of training). Additionally, a dose curve relationship should be established by using varying doses of caffeine.

BIBLIOGRAPHY

Axelsson, J. and Thesleff, S. Activation of the contractile mechanism in striated muscle. ACTS Physiol. Scand., 44, 55-66, 1958.

Bianchi, P. C. and Narayan, S. Muscle fatigue and the role of transverse tubules. Science, 215, 295-296, 1982.

Bond, V. et al. Caffeine ingestion and isokinetic strength. Br. J. Sports Med., 20(3), 135-137, 1986.

Bosworth, B. and Reilly, R. The Boz: Confessions of a Modern Anti-Hero. New York: Doubleday, 1988.

Bugyi, G. J. The effects of moderate doses of caffeine on fatigue parameters of the forearm flexor muscles. Amer. Corr. Ther. J., 34(2), 49-53, 1980.

Butts, N. K. and Crowell, D. Effect of caffeine ingestion on cardiorespiratory endurance in men and women. Res. Qrtly. for Exer. and Sport, 56(4), 301-305, 1985.

Chuck, L. H. S. and Parmley, W. W. Caffeine reversal of length-dependent changes in myocardial contractile state in the cat. Dir. Res., 47, 592-598, 1980.

Colton, T.; Gosselin, R. E.; and Smith, R. P. The tolerance of coffee drinkers to caffeine. Clin. Pharmacol. Ther., 9, 31-39, 1968.

Costill, D. L.; Datsky, G. P.; and Fink, W. J. Effects of caffeine ingestion on metabaolism and exercise performance. Med. Sci. Sports Exer., 10(3), 155-158, 1978.

Davies, G. J. Computerized Cybex testing of ACL reconstructions assessing quadriceps peak torque, TAE, total work and average power. Med. Sci. Sports Exer., 16, 204, 1984.

Erickson, M. A.; Schwarzkopf, R. J.; and McKenzie, R. D. Effects of caffeine, fructose, and glucose ingestion on muscle glycogen utilization during exercise. Med. Sci. Sports, Exer., 19(6), 579-582, 1987.

FDA Consumer. Caffeine Studies Urged. February, 1981.

Fisher, S. M. et al. Influence of caffeine on exercise performance in habitual caffeine users. Int. J. Sports Med., 7, 276-280, 1986.

Fleck, S. J. and Kraemer, W. J. Designing Resistance Training Programs. Champaign, Illinois: Human Kinetics, 1987.

Fox, E. L. Sports Physiology. Philadelphia: W. B. Saunders, 1984.

Frank, G. B. Pharmacological studies of excitation-contraction coupling in skeletal muscle. Can. J. Physiol. Pharmacol., 65, 711-716, 1986.

Gaesser, G. A. and Rich, R. G. Influence of caffeine on blood lactate response during incremental exercise. Int. J. Sports Med., 6, 207-211, 1985.

Graham, D. M. Caffeine: Its identity, dietary sources, intake and biological effects. Nutr. Rev., 36(4), 97-102, 1978.

Ivy, J. L. et al. Influence of caffeine and carbohydrate feeding on endurance performance. Med. Sci. Sports Exer., 11, 6-11, 1979.

Jacobson, B. H. The effects of varying doses of caffeine on peak torque in knee extensors and knee flexors (in press), 1989.

Jacobson, B. H. and Edgley, B. Effects of caffeine on simple reaction time and movement time. Aviat. Space Envir. Med., 58, 1153-1156, 1987.

Kots, Y. M.; Vinogradova, O. L.; and Danicheva, E. D. Metabolic rate of caffeine during muscular work depending on the carbohydrate reserves level. Fiziologiya Cheloveka, 10(2), 310-316, 1984.

LeBlanc, J. et al. Enhanced metabolic response to caffeine in exercise-trained human subjects. J. Appl. Physiol., 59(3), 832-837, 1985.

Leonard, T. K.; Watson, R. D.; and Mohs, M. E. The effects of caffeine in various body systems: A review. J. Am. Diet. Assoc., 87(8), 1048-1053, 1987.

Lopes, J. M. et al. Effect of caffeine on skeletal muscle function before and after fatigue. J. Appl. Physiol., 54, 1303-1305, 1983.

McNaughton, L. R. The influence of caffeine ingestion on incremental treadmill running. Br. J. Sports Med., 20(3), 109-112, 1986.

Marcus, J., Ed. Sports Nutrition. Chicago: American Dietetics Association, 1986.

Nassar-Gentina, V.; Passonneau, J. V.; and Rapoport, S. I. Fatigue and metabolism of frog muscle fibers during stimulation and in response to caffeine. Am. J. Physiol., 241 (Cell Physiol. 10): C160-C166, 1981.

Partin, N. Medical update: Effects of caffeine on athletes. Athletic Training, 23(3), 286-287, 1988.

Robertson, D. et al. Tolerance to the humoral and hemodynamic effects of caffeine in man. J. Clin. Invest., 67, 1111-1117, 1981.

Rothstein, J. M. et al. Electromyographic, peak torque, and power relationships during isokinetic movement. Phys. Ther., 63(6), 926-933, 1983.

Stamford, B. Exercise adviser: Caffeine and athletes. Med. Sci. Sports Exer., 17(1), 193-194, 1989.

Telander, R. The big enchilada. Sports Illustrated, 70(18), 40-49, April 24, 1989.

Weber, A. The mechanism of the action of caffeine on sarcoplasmic reticulum. J. Gen. Physiol., 52, 760-722, 1968.

Weber, A. and Herz, R. The relationship between caffeine contracture of intact muscle and the effect of caffeine on reticulum. J. Gen. Physiol., 68, 766-722, 1968.

Weir, J. et al. A high carbohydrate diet negates the metabolic effects of caffeine during exercise. Med. Sci. Sports Exer., 19(2), 100-105, 1987.

Wood, D. S. Human skeletal muscle: Analysis of calcium regulation in skinned fibers using caffeine. Exp. Neurol., 58, 218-230, 1978.

Williams, J. H.; Barnes, W. S.; and Gadberry, W. L. Influence of caffeine on force and EMG in rested and fatigued muscle. Am. J. Phys. Med., 66(4), 169-183, 1987.

Williams, J. H. et al. Caffeine, Maximal power output and fatigue. Brit. J. Sports Med., 22(4), 132-134, 1988.

APPENDIXES

APPENDIX A

CONSENT FORM DOCUMENT

Human Subjects Consent Form

Oklahoma State University

Individual's Consent for Participation in a Research Project

I, _____ voluntarily agree to participate in this study entitled: "The Effect of Caffeine on Peak Torque and Muscle Endurance in the Knee Extensors and Flexors."

1. Purpose. This study involves research that will be carried out under the supervision of Bert H. Jacobson, Ed.D. (principal investigator), Steven Edwards, Ph.D., and Mickey Weber, B.S. The purpose of this study is to investigate the effects of caffeine ingestion on peak torque and power in man during low, moderate, and high speeds of contraction.

2. Status of Investigational Drug Procedures. Caffeine may alter blood pressure, heart-rate, respiration, and metabolic rate. Caffeine may also induce tremors, nervousness, and anxiety.

3. Description of Study. A caffeine consumption questionnaire will be administered to ascertain the average amount of caffeine consumed per day and week. Any subject indicating a blood pressure reading above 140 mm/Hg systolic pressure and/or 99 mm/Hg diastolic pressure and tachycardia will be eliminated from the study.

The team physician will eliminate any subject with: a history of any cardiac or vascular disorder, a stomach or intestinal disorder, a mental or emotional disorder, currently on medication, or currently ill.

Subjects will be asked to fast (food) for eight hours and fast from caffeine four days prior to testing. Subjects will be pretested to establish existing strength levels. Following the pretest, each subject will be given one of two oral capsules containing: (1) anhydrous caffeine (7 mg/kg) or (2) a placebo (225 mg. methycellulose) on a double-blind format. Following a one hour waiting period, all subjects will be posttested using the pretest protocol.

The full duration of this study will take approximately one and one-half hours.

I understand that I will be assiend to one of two groups and given 7 mg. caffeine/kg bodyweight, or 225 mg. methycellulose and the group that I have been assigned to is selected at random, by chance. Neither I nor the investigator knows which group I have been assigned to, but that information can be obtained, if necessary.

4. Benefits. No direct benefit in the consumption of caffeine may be expected. However, observable physical changes may lead to a change in attitude toward caffeine consumption and a greater awareness of products containing caffeine may ensue.

5. Possible Risks. Caffeine ingestion in the quantities described in this study may increase nervousness, irritability, and anxiety. Respiration, blood pressure, and heart rate may also be altered. Additionally, nausea may appear if the meal following caffeine consumption includes spicy and/or greasy food. STAY AWAY FROM PIZZA!

If you become nauseous or feel ill, you will be retained for observation and transported to the University Health Center.

I recognize that the primary risk is the possibility of experiencing some side effects. Those that have been observed in the past for caffeine consumption include: hyperactivity, upset stomach after eating pizza.

If I have any side effects, I will report them immediately to the investigator, my physician, or his/her associates. If side effects are severe, I may be removed from the study.

6. Alternate Procedures. None

7. Subject Assurances. Whereas no assurance can be made concerning results that may be obtained (because results from investigational studies cannot be predicted with certainty), the principal investigator will take every precaution consistent with best scientific practice.

By signing this consent form, I acknowledge that my participation in this study is voluntary. I also acknowledge that I have not waived any of my legal rights or released this institution from liability for negligence.

I may revoke my consent and withdraw from this study at any time without penalty or loss of benefits. My treatment by the relationship with the investigator and staff at Oklahoma State University, now and in the future, will not be affected in any way if I refuse to participate, or if I enter the program and later withdraw.

Records of this study will be kept confidential with respect to any written or verbal reports, making it impossible to identify me individually. All records will be held in a locked file belonging to the principal investigator.

If I have any questions about my rights as a research subject, I may take them to the Office of University Research Services, 001 Life Science East, telephone: 744-9991.

8. Signatures.

_____	_____
Date	Research Subject
_____	_____
Date	Witness
_____	_____
Date	Principal Investigator

Any questions regarding the research may be addressed to Bert Jacobson, Principal Investigator, 103 Colvin Center. Telephone: 744-5493.

Subjects will receive a copy of this consent form following the investigation.

APPENDIX B

CAFFEINE CONSUMPTION QUESTIONNAIRE

Caffeine Consumption History

Vital Statistics

Medical History

Name _____ Age _____ Sex _____

Weight_____ Height_____

% Body Fat _____

Pre Hr. _____ Pre BP _____

Post _____ Post _____

Caffeine Consumption History:

Coffee: Cups/day _____avg.

Soft Drinks (Coke, Dr. Pepper, Mt. Dew, Pepsi, etc.)/day _____ avg.

Tea: Cups/day _____ Glasses/day _____

Other: (explain) _____

How does caffeine affect you? _____

_____

Have you ever experienced or know of:

Heart trouble	_____	Stomach disorder	_____
Intestinal disorders	_____	High blood pressure	_____
High heart rate	_____	Mental/emotional disorders	_____

Are you currently on medication? _____ If so, explain _____
Are you suffering from a hangover? _____
Do you think you are pregnant? _____
Are you currently taking oral contraceptives? _____
Are you suffering from lack of sleep? _____

Have you fasted for eight hours? _____

Last meal was _____ hours ago.

Last caffeine was consumed _____ hours ago in the form of _____

_____ Time of ingestion _____ Time of testing

Group #_____

Years of resistance training _____

APPENDIX C

HANDOUT TO SUBJECTS (PRETEST)

Dietary Restrictions

You are one of 20 subjects I have selectively chosen for my research. I chose you for the following reasons:

1. You have the ability to push yourself.
2. You are conscientious enough to understand the importance of following directions and being on time.

This research is the last step towards my master's degree, so I cannot stress enough the importance of your participation. The study requires all 20 subjects. I will call you the night before you are to come in to do the testing to remind you of your time. The schedule you must follow in order to get the results I need is listed below.

Thursday

No caffeine--I have included a sheet listing the products you will need to avoid. If you must drink soda pop, drink Sprite, 7-Up, or ginger ale (beer is also fine, in moderation). No tea or coffee in any amounts.

Friday

No caffeine.

Saturday

No caffeine. Limit high carbohydrate foods: fruits, potatoes, rice, and pasta noodles. Limit activity.

Sunday

Same schedule as Saturday.

Monday, June 12 and 19

Testing time _____

I sincerely thank you for your participation. Without you, this project would not be possible. Thanks again.

Caffeine Content of Beverages and Food

	Average
Coffee (5 oz cup)	
Brewed, drip method	115 mg
Instant	65
Tea (5 oz cup)	
Brewed, major U.S. brands	40
Instant	30
Iced (12 oz glass)	70
Cocoa beverage (5 oz cup)	4
Chocolate milk beverage (8 oz)	5
Milk chocolate(1 oz)	6
Dark chocolate, semi-sweet (1 oz)	20
Chocolate-flavored syrup (1 oz)	4
Soft Drinks	
Mountain Dew	54.0
Mello Yello	52.8
TAB	46.8
Coca-Cola	45.6
Diet Coke	45.6
Mr. Pibb	40.8
Dr. Pepper	39.6
Sugar-Free Dr. Pepper	39.6
Pepsi-Cola	38.4
Diet Pepsi	36.0
Pepsi Light	36.0
Kick	31.2
Club Soda	0
7-up	0
Fresca	0
Sprite	0
Ginger ale	0

APPENDIX D

SUBJECTS' WEIGHT AND CAFFEINE INGESTION DOSAGE

Subjects' Weight and Caffeine Ingestion Dosage

Subject No.	wt/lbs	wt/kg	Caffeine mg/kg
1	245	111	780
2	245	111	780
3	235	107	750
4	178	81	570
5	184	84	590
6	184	84	590
7	250	113	795
8	270	122	860
9	250	113	795
10	230	105	735
11	270	122	860
12	172	78	550
13	200	90	635
14	250	113	795
15	220	100	700
16	183	83	580
17	183	83	580
18	180	81	570
19	222	101	705
20	240	108	760

APPENDIX E

RESPONSIBILITIES OF RESEARCHERS DURING TESTING

Responsibilities of Assistant Number 1

1. Make wake-up calls to subjects 30 minutes before testing begins.

2. Greet subjects and explain procedures.

    a. room must remain quiet
        1. no external motivation for subject being tested
        2. no conversing in testing area

    b. explain steps in the test
        1. pretest
        2. take substance from Dr. Jacobson
        3. one hour absorption period
        4. posttest

3. Put subjects in a testing order and prepare next subject for testing.

4. Put Cybex printed data in folders at the completion of each test.

5. Place caffeine questionnaires in folders after they have been filled out.

6. Debrief subjects after final test.

Responsibilities of Assistant Number 2

1. Tell subjects to remove shoe and sock of right foot.

2. Strap subjects onto Cybex at four locations.

    a. chest
    b. waist
    c. knee
    d. ankle--four inches above lateral condyle

3. Align lever arm rotational point to center of the subject's knee.

4. Record lever arm ankle setting on subject's folder.

5. Tell players to:

    a. fully extend leg at the knee on each repetition
    b. touch heel pad with heel to complete each repetition
    c. grab the seat pad with hands for support

6. Count the repetitions out loud for each set.

7. Time the one-minute interval between each set, using a stopwatch.

8. Unstrap subject from Cybex upon completion of third set.

Responsibilities of Dr. Bert Jacobson During Testing

1. Give substance to subjects after completion of pretest. Knowledge of caffeine or placebo subjects is known only to you.

2. Explain possible ill effects of drug and remind subjects not to converse about the test or physical symptoms during the one-hour absorption period.

3. Tell subjects to wait in adjacent waiting room to be recalled for posttest.

4. Give caffeine questionnaire to subjects to be filled out in waiting room during absorption period.

5. Record time of substance ingestion.

Responsibility of Author During Testing

1. Explain to subjects that maximal exertion on each repetition is required on each set.

2. Explain the test:

    a. three sets will be performed
        1. one-minute rest period
        2. 3 repetitions on set one, 3 repetitions on set two, and 20 repetitions on set three.

3. Run the Cybex data analysis on computer.

VITA

Mickey Dale Weber

Candidate for the Degree of

Master of Science

Thesis: THE EFFECT OF CAFFEINE ON PEAK TORQUE AND MUSCLE ENDURANCE IN THE KNEE EXTENSORS AND FLEXORS

Major Field: Health, Physical Education and Recreation

Biographical:

Personal Data: Born in Oklahoma City, Oklahoma, July 19, 1962, the son of Franklin D. and Jacque Weber.

Education: Graduated from Yukon High School, Yukon, Oklahoma, in May, 1980; received Bachelor of Science in Arts and Sciences degree from Oklahoma State University in December, 1985; completed requirements for the Master of Science degree at Oklahoma State University in May, 1990.

Professional Experience: Assistant Strength and Conditioning Coordinator, Oklahoma State University, December, 1985 to December, 1989; Strength and Conditioning Coordinator, Illinois State University, January, 1990 to present.