THE EFFECTS OF VARYING DOSES OF CAFFEINE ON PEAK TORQUE IN THE KNEE EXTENSORS AND KNEE FLEXORS

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CHAPTER I

INTRODUCTION TO THE PROBLEM

History of Caffeine

Caffeine, an alkaloid structurally identified as xanthine derivative 1,3,7-Trimethylanthine (16), is presently the most widely used social drug in the world. Xanthine compounds, of which caffeine is a member, as well as theobromine and theophylline can be traced to 4700 B.C. in China where the consumption of tea was common (24). Historically, Arabians used the coffee bean and Mexicans the cocoa bean for xanthine consumption (6); the kola nut and its usefulness was discovered some time later.

A survey in 1981 notes that the average American drinks nearly thirty-two gallons of soft drinks and about twenty-eight gallons of coffee annually, both of which contain varying levels of caffeine (13). Geographically, sources of caffeine can also be found in sixty trees and plants, ranging all over the world, and many other less known sources (40).

Methyl derivatives of xanthine (2,6-Dihydroxypurine), the stimulating compounds present in caffeine, are naturally occurring chemicals (40). Caffeine is absorbed into the blood stream from the gastrointestinal tract, reaching

peak concentrations between thirty to sixty minutes after ingestion regardless of the dose (39). According to Burg (4), the caffeine has a half-life of 2.0-2.8 hours in the bloodstream and no significant amount remains after 24 hours (40).

Caffeine shows a variety of both neurological and biological effects on the human body. According to Graham (16), caffeine primarily acts as a cerebral stimulator, theophylline in tea acts as a coronary dialator, and theobromine from cocoa acts as a diuretic. General actions of caffeine include stimulation of the central nervous system, skeletal muscle, and kidneys (16, 40). The effects on the cardiac muscle and cardiovascular system indicate that caffeine may alter contractility, blood pressure, blood flow, and even cardiac output (39). Many studies have cited that caffeine has an effect of prolonged endurance during exercise as a result of caffeine's link to enhanced mobilization and utilization of free fatty acids (39, 1, 8, 23). Caffeine also has an effect on reaction and movement times, hand steadiness, alertness, perception, and wakefulness (39).

Although caffeine is found in many sources ranging from trees and plants to beans and nuts, once the caffeine is extracted from its organic state and processed, its marketed scope broadens. Some of the dietary sources containing caffeine include coffee, tea, soft drinks, baked goods, frozen dairy goods, gelatins, puddings, chocolate and soft

candies (24) (Tables I and II). Many common medications, both prescription and nonprescription, contain caffeine in varying amounts (9) (Table III). With the wide scope of products containing caffeine, people of all ages are subject to ingesting caffeine through their daily dietary habits or medical needs.

There are some suspected medical drawbacks associated with caffeine ingestion at various dosages. High levels of caffeine may produce insomnia, nervousness, irritability, anxiety, and disturbances in the heart rate and circulation (9). Pregnant and lactating women are now being cautioned by members of the medical profession and the Food and Drug Administration (FDA) against consuming caffeine. This warning has been issued due to the drug's ability to cross the placenta barrier and enter the developing fetus and breast milk (38). Some inclusive studies have suggested a correlation between caffeine consumption and heart disease, pancreatic cancer, and fibrocystic disease (38). In 1981, the FDA encouraged studies of various effects of caffeine, including the effect of long-term feedings of rats to investigate a possible correlation to cancer and other pathological effects, and the possibility of caffeine inducing adverse behavioral effects (12).

Possible ergogenic effects of caffeine ingestion will be formally addressed in the Chapter II.

TABLE I

CAFFEINE CONTENT OF BEVERAGES AND FOODS

Item	Milligrams Caffeine Average	Range
Coffee (5 oz. cup)		
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 oz. cup)		
Brewed, major U.S. brands	40	20-90
Brewed, imported brands	60	25-110
Instant	30	25-50
Iced (12 oz. glass)	70	67-76
Cocoa beverages (5 oz. cup)	4	2-20
Chocolate milk beverage (8 oz.)	5	2-7
Milk chocolate (1 oz.)	6	1-15
Dark chocolate, semi-sweet (1 oz.)	20	5-35
Baker's chocolate (1 oz.)	26	26
Chocolate-flavored syrup (1 oz.)	4	4

Source: FDA, Food Assistive Chemistry Evaluation Branch, based on evaluations of existing literature on caffeine levels.

TABLE II

CAFFEINE CONTENT OF SOFT DRINKS

Brand	Milligrams Caffeine (12 oz. 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, based on data from National Soft Drink Assocation, Washington, D.C. IFT also reports that there are at least 68 flavors and varieties of soft drinks produced by 12 leading bottlers that have no caffeine.

TABLE III

CAFFEINE CONTENTS OF PRESCRIPTION AND NONPRESCRIPTION DRUGS

Prescription Drugs	Milligrams Caffeine
Cafergot (For Migraine Headaches)	100
Fiorinal (For Tension Headaches)	40
Soma Compound (Pain Relief, Muscle Relaxant)	32
Darvon Compound (Pain Relief)	32.4
Nonprescription Drugs	**Milligrams Caffeine**
Weight Control Aids	
Codexin	N/A
Dexa-Diet II	200
Dexatrim, Dexatrim Extra Strength	200
Dietac Capsules	200
Maximum Strength Appendrine	100
Prolamine	140
Alertness Tablets	
Nodoz	100
Vivarin	200
Analgesic/Pain Relief	
Anacin, Maximum Strength Anacin	32
Excedrin	65
Midol	32.4
Vanquish	33
Diuretics	
Aqua-Ban	100
Maximum Strength Aqua-Ban Plus	200
Permathene H2 Off	200
Cold/Allergy Remedies	
Coryban-D Capsules	30
Triaminin Tablets	30
Dristan Decongestant Tablets and Dristan A-F Decongestant Tablets	16.2
Duradyne-Forte	30

Source: FDA's National Center For Drugs and Biologics

Statement of the Problem

It was the purpose of this study to determine the effects of varying dosages of caffeine ingestion upon the peak torque and ratio of peak torque and bodyweight of the knee extensors and knee flexors in college students. This study was undertaken to 1) determine if varying dosages of caffeine indicate a marked increase in musculoskeletal strength from a pre-ingestion test to a post-ingestion test, and 2) to determine the effects of caffeine on muscle fatigue at high speeds of contraction.

Hypotheses

The specific hypotheses tested were of caffeine ingestion upon peak torque and ratio of peak torque and bodyweight in an indicated limb movement. This study attempted to determine if varying caffeine dosages affects musculoskeletal strength. It was also the purpose of this investigation to determine the effects of caffeine on the ratio of peak torque and bodyweight. The following hypotheses were tested:

HO_1: There is no significant difference between the control group and two experimental groups in peak torque at a speed of 75 degrees per second.

HO_2: There is no significant difference between the control group and two experimental groups in peak torque at a speed of 180 degrees per second.

HO_3: There is no significant difference between the control group and two experimental groups in peak torque at a speed of 300 degrees per second.

HO_4: There is no significant difference between the control group and two experimental groups in a ratio of peak torque and bodyweight at a speed of 75 degrees per second, at a thirty-degree angle.

HO_5: There is no significant difference between the control group and two experimental groups in a ratio of peak torque and bodyweight at a speed of 180 degrees per second, at a thirty degree angle.

HO_6: There is no significant difference between the control group and two experimental groups in a ratio of peak torque and bodyweight at a speed of 300 degrees per second, at a thirty degree angle.

Limitations of the Study

1. The total number of students volunteering for the study was fifteen.

2. The fifteen subjects, eleven males and four females, were divided into three groups consisting of five subjects in each group.

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

4. The test subjects were asked to being a complete fast, with the exception of water, beginning at noon of the assigned testing day until the 7:30 p.m. starting time.

5. The participating subjects, with the exception of the subject being tested, were asked to wait in another room. During the test, only the testing personnel were allowed in the room with the subject.

6. All the subjects were tested on their dominant side.

Significance of the Problem

Several studies in vitro have been completed on skeletal muscle action in insect and animal subjects, but there are currently only two studies dealing with musculoskeletal strength involving human subjects. One study relied on electrical stimulation to elicit a maximal muscular contraction (26), and the other depended on the subjects to give a maximal voluntary contraction (3). The investigations were equivocal to one another, thus indicating the need to further investigate the effects of caffeine dosages on peak torque and endurance using maximal voluntary contractions. Such findings may also have value as a basis in sports medicine and athletic competition.

CHAPTER II

HISTORY AND LITERATURE REVIEW

Since the beginning of athletic competition, athletes have searched for a means of gaining the competitive edge over their rivals. Many athletes have searched for these means through the use of ergogenic aids, which may be defined as anything that may enhance work or the potential for work output (37). Caffeine may be considered an ergogenic aid because of its stimulating effect on the central nervous system. Anthropologists believe, according to Slavin and Joenson (36) and Eicher (11), that caffeine has been used as a stimulant since the stone age.

Percy (32) states that stimulants have been used since time immemorial in athletic endeavors; their use was even reported in the first Olympiads circa 776 B.C. The first proven cases of drug abuse in sports, according to McGraw-Hill World News Correspondents and Physician and Sports Medicine writers (29), occurred in in 1865 when Amsterdam canal swimmers and French racers were caught using caffeine-containing drugs. The report states that by the 1930's American athletes were pouring powdered gelatin into orange juice with the belief that it improved performance. Use of caffeine as an ergogenic aid surfaced again during the summer Olympic Games in 1984 at Los Angeles. According to

Rogers (34), six to ten American cyclists experimented with caffeine suppositories in an attempt to capitalize on caffeine's ergogenic effects in preparation for the games.

Lombardo (25) states that stimulants are popular as ergogenic aids because of their ability to mask, delay, or alter the athlete's perception of fatigue. He adds that the enhanced performance associated with the use of caffeine is limited to endurance activities. Van Handel (40) postulates that caffeine is one of the few drugs capable of enhancing athletic performance. This statement was well received by many in the athletic world. Dardik (10) reports that many athletes and their advisers see performance enhancing drugs such as caffeine as a "breakthrough" in sports medicine. However, Hage (18) reported that in 1982 caffeine was added to the banned drug list for olympic athletes because it is considered an ergogenic aid. The same list was adopted by the National Collegiate Athletic Association in 1986 for its drug testing program (30). Lombardo (25) reports that a positive result on the urinalysis is indicated by caffeine values in the urine which meet or exceed 15ug-ml-1.

Eicher (11), based on results obtained from eight studies, believes that caffeine may be an ergogenic aid through psychoneurologic rather than metabolic means.

The usefulness of caffeine as an ergogenic aid has thus far centered on its ability to enhance endurance activities, but there have also been studies linking caffeine enhanced

reaction time and movement time and muscle contractile properties in both animals and humans, and possibly strength.

Caffeine and Endurance

Van Handel (39) reported that caffeine may enhance endurance because of its ability to inhibit glucose and muscle glycogen use, resulting in a glycogen sparing effect that allows the body to use fats as fuel during the middle portion of exercise lasting over sixty minutes.

Bellet and Kershbaum (1) administered 250 mg of caffeine to five normal males and recorded blood samples at one, two, three and four hours after ingestion. The study showed a rise in free fatty acids (FFA) in all the subjects, with the peak concentration occurring three to four hours after ingestion. The mean increase in FFA concentration was 92% above the initial pre-caffeine sample.

Margaria, Aghemo, and Revelli (28) studied the effects of caffeine on endurance. Three subjects ingested caffeine dosages of 100 mg and 250 mg 90 minutes prior to running on a treadmill at either 12 km/h or 13.8 km/1. The data collected gave no indication that the levels administered increased the maximal capacity of athletic performance for the dosages given or for the type of exercise used in the investigation.

Perkins and Williams (33) studied the physiological effects of caffeine on fourteen athletes by administering dosages of 4, 7, and 10 mg/kg of bodyweight. The subjects

then pedaled on a stationary bike until exhaustion. The results of this experiment indicated that caffeine, in the dosages administered, imparts no physiological benefit to an individual while exercising.

A similar study conducted by Ivy, Costill, Fink, and Lower (23) resulted in contradictory conclusions. In this experiment, nine trained cyclists were administered 250 mg of caffeine sixty minutes prior to the beginning of a two-hour ride. Following the start of the test, the caffeine group was given an additional 250 mg at fifteen-minute intervals during the first ninety minutes. Results indicated that caffeine ingestion significantly enhanced the production of work, and that during the last hour of the test the caffeine group showed a steady increase in work output over the two noncaffeine groups. The study also demonstrated that caffeine ingestion in the amounts and procedures used significantly increased the amount of work that could be accomplished during a two-hour cycling exercise.

Similarly, Costill, Dalsky, and Fink (8) administered 330 mg of caffeine to nine competitive cyclists. The test involved cycling at 80% Vo2 max until exhaustion. The data indicated that the subjects who had ingested the caffeine solution showed an increase of total time to exhaustion of 19.5% over the subjects who had ingested a placebo.

Caffeine and Movement Time

Osborne and Rogers (31) investigated the combined effect of caffeine and alcohol on reaction time. The subjects ingested 65.5 degrees proof vodka in the quantity of 2.2 ml/kg of bodyweight and 150 mg of caffeine. Reaction time was based on the subject's reaction to recognizing components of a memory set, already learned, as they appeared on a computer screen. The results indicated that caffeine has the effect of potentiating the detrimental effects induced by alcohol, which was a significant retardation of reaction time.

Carpenter (5) studied the effects of 1.47 mg and 2.94 mg/kg caffeine per kg of bodyweight on nine graduate students. Measurement was on visual reaction time. The study suggests that caffeine produces small reductions in reaction time when certain conditions are present, which in this study included high intensity stimulation and a high alcohol dosage: .80/ml/kg of bodyweight using ninety proof whisky mixed with ginger ale.

Schilling (35) investigated auditory reaction time on twenty student volunteers. Using 320 mg of caffeine, Schilling noted that caffeine retarded reaction time.

Cheney (7) evaluated the effects of 300 cc of black coffee and three grains of caffeine on five female subjects. Using a simplified modification of Dr. Metfressel's psychodometer, which measures the time elapse from light stimulus illumination to the subject pressing the proper tap-key.

Cheney clearly demonstrated that both the caffeine and coffee reduced the reaction time under a caffeine dosage of 3.3 mgm to 3.6 mgms/kg of bodyweight over a three-hour period.

Flory and Gilbert (14) studied the effects of five grains of caffeine citrate on forty-three college students' reaction time. The subjects were asked to perform three tapping tests (tapping as many times as possible in a ten-second period). The results measured the difference between test one and test three. Both the control group and the caffeine group showed gains, but the control group showed a slightly greater increase. Flory and Gilbert attribute this to the psychological effect of suggestion being as stimulating as caffeine for these subjects, and concluded that there is no evidence from the results to indicate that students in general can improve their efficiency by the use of caffeine citrate.

Caffeine and Skeletal Muscle

Studying the extensor longus digiti IV of a frog, Frank (15) states that caffeine elicited a contracture by releasing calcium from some binding site in or on the muscle itself.

Huddart and Abram (20) studied the effects of 2 mM/1 of caffeine on the metathoracic extensor ibialis muscle in the locust. Data indicated that caffeine produced a modification of excitation-contraction by a facilitation of calcium release from the sarcoplasmic reticulum and suppression of

active calcium binding by the sarcoplasmic reticulum which prolonged the active state of the muscle. Huddart and Abram also point out that caffeine significantly lowered the mechanical threshold.

Gutmann and Sandow (17) studied the effects of 20 mM of caffeine on a normal and denervated rat muscle. Caffeine caused a potentiation of skeletal muscle contraction by prolonging the active state and thus increasing twitch tension. However, caffeine did not alter the maximal capacity of the active state to produce tension or change tetanus strength.

Studying the flexor tibialis muscle of the stick insect, Huddart (19) concluded with the suggestion that caffeine may induce contractures by accelerating calcium release and inhibiting reactivation of the calcium pump by a direct effect on the sarcoplasmic reticulum of the muscle cell. The study also showed that 1-2 mM/1 of caffeine enhances twitch and tetanus tension output in stick insect skeletal muscle.

Huddart (22) studied the effect of caffeine on the skeletal muscle of the crab. In the study, caffeine modified the excitation-contraction coupling by lowering the mechanical threshold, and reduced the onset of fiber shortening and increased the rate of tension development. Huddart also states that caffeine significantly lowered the membrane potential level at which tension can be developed and makes the sarcoplasmic reticulum hypersensitive to deplorizatio-

Weber and Hart (41) studied the effects of 1 to 10 mm of caffeine on the leg muscles of the frog, and the leg and back muscles of the rabbit. In the frog, caffeine caused the release of calcium from the reticulum in amounts large enough to account for the force of contracture produced. In the rabbit, caffeine inhibited the rate of calcium uptake, which may in part account for the prolongation of the active state of the contracture caused by the caffeine.

Luttgau and Oetliker (27) studied single fibers of the semitendinous muscle from the Swiss mountain frog, using 1 to 10 mm of caffeine. Data showed that 1-10 mm caused reversible contractures, while 1-2 mm of caffeine produced a potentiation of contraction. The investigators concluded that while caffeine in low concentrations has no effect on the electrical characteristics of the excitable membrane, caffeine in low concentrations does reduce the mechanical threshold. The study also points out that after the addition of caffeine, phasic muscle fibers acquire the ability to maintain maximal tension for long periods of time.

Bianchi (2) studied the sartorius muscle of the frog using 0.005 m of caffeine. Bianchi concluded that a caffeine level of 0.005 m increased the muscle twitch height but caused no observable contracture for periods up to five minutes.

One study by Huddart and Oates (21) pointed out the possible damaging effects of caffeine on the muscle cell. Using 10 mM on skeletal muscle from the frog and the cray-

fish, the authors concluded that exposure of muscle to a caffeine level of 10 mM resulted in the rapid dilation of the sarcoplasmic reticulum tubules, resulting in possible damage to the sub-cellular structures involved in excitation-contraction coupling.

Wood (42) studied the effects of caffeine on biopsies from the quadriceps muscles of three adults in relation to contractile effects. Wood concluded that in human muscle, the rapid tension development after the caffeine application resulted primarily from an increased passive calcium ($Ca2^{+}$) permeability of the sarcoplasmic reticulum which leads to a raid efflux of $Ca2^{+}$.

Caffeine and Muscle Strength

Lopes et al. (26) studied the effect of 500 mg of caffeine on voluntary and electrically stimulated contractions of the adductor pollicis muscle in five adults. The data showed that caffeine ingestion produced an increase in the tension developed in the muscle, suggesting a direct effect on muscle contraction. The amount of tension developed was similar in both the rested and the fatigued muscles, although there was a 20% decline in the fatigued muscle in response to electrical stimulation. Also, the tension developed during low levels of stimulation and not at the higher level of stimulation.

Bond et al. (3) studied the effect of caffeine on isokinetic strength in twelve male intercollegiate sprint-

ers. Bond et al. used a cross over design in the statistical analysis of the study. The subjects ingested 5 mg/kg of caffeine, or a placebo, then rested in a sitting position for sixty minutes before the start of the test. The subjects were then tested, using a Dual Channel Cybex II Isokinetic Dynamometer connected to a Cybex II Data Reduction Computer, for dominant knee extension and knee flexion strength. Bond et al. concluded that caffeine in small dosages exerts no influence on muscle function at low, moderate and high contracting velocities tested in vivo.

The research by Bond et al. (3) and Lopes et al. (26) are currently the only noted research concerning the effects of caffeine on skeletal muscle strength and tension development. In the conclusion of their research article, Bond et al. make a recommendation to extend research involving the effects of caffeine and skeletal muscle strength with the suggestion of utilizing a larger dose of caffeine.

Summary

The articles presented in this section suggest that the action of caffeine centers on its ability to effect the sarcoplasmic reticulum. Caffeine, when introduced to the muscle cellular system causes a rapid dilation of the sarcoplasmic reticulum tubules, which alters the release, uptake, or storage of calcium by the sarcoplasmic reticulum. Caffeine causes an increase of calcium uptake by the calcium pump in the sarcoplasmic reticulum, causing an increased

potentiation for skeletal muscle contractility. The calcium availability may be a result of caffeine's ability to release calcium from binding sites in or on the muscle. It is also believed that caffeine inhibits the reactivation of the calcium pump, causing a prolonged active state and increasing tension.

CHAPTER III

METHODS

Subjects

The fifteen subjects, eleven males and four females had a mean age of 20.5 years old and mean weight of 159 pounds, used for this study were students at Oklahoma State University, Stillwater, Oklahoma. The subjects were asked to volunteer for the study after the procedure and the scope of the study were explained to them. The subjects were members among anatomy classes at the university. After the subjects verbally consented to participate in the study, they were asked to sign a consent document (Appendix A). The consent document outlined the procedures of the study and required the subjects to sign their names indicating that they understood the procedures involved.

Method of Collecting Data

Prior to testing, a consumption history (Appendix B) and physical screening form (Appendix B) were completed by each subject. The subjects completed their questionnaire form in an adjoining room upon arrival at the test site. Recorded on the questionnaire was the subject's resting heart rate, blood pressure and normal caffeine consumption.

Upon completing the information questionnaire, each subject chose a number that was recorded in the upper right hand corner of the information form. This randomly assigned number indicated the testing group to which the subject was assigned.

Instructions were given and the entire procedure explained to the group before individual testing began. To facilitate control and insure a quiet testing environment, only the investigator and his three assistants were allowed in the testing area during individual testing. The remaining subjects waited in an adjacent room, removed from the testing area. Upon completing his/her pre-test, the subject ingested one of the predetermined solutions in the testing area before returning to the waiting area. All subjects were treated in the same manner.

The caffeine concentrations, 0 mg., 300 mg., and 600 mg. were mixed in the testing area. The subjects were asked to ingest the concentration within a three-minute period upon completing the pre-test. The time of complete consumption was noted and placed on the individual information forms. This procedure served the purpose of indicating when sixty minutes had passed since ingestion.

Equipment and Caffeine Administration

The Cybex II+ (a division of Lumex, Inc., Bay Shore, New York) was utilized in measuring the torque productions of the knee joint. The Super Heavy Duty (S-H-D) single

width table seat was utilized for the ranges of extension and flexion. Velcro stabilization straps were secured across the thigh and around the pelvic area. The tibial contour pad, attached to the long adjustable arm, was secured by a velcro strap around the lower one-third of the dominant leg. The adjustable arm was connected to the Isokinetic Dynamometer which was connected to the Dual-Channel Recorder. The junction of the long arm and the Isokinetic Dynamometer was aligned so that its axis passed through the axis of the subjects knee. A Dual-Channel Recorder produced a chart of torque production and all primary information on the subject such as name and weight were introduced into the Cybex Data Reduction Computer (C.D.R.C.), including the speeds of contraction controlled by the RDSC speed selector.

Caffeine was administered from 100 mg tablets. The tablets were crushed in a ceramic pharmacist mixing bowl, then mixed with 250 ml of heated water and one-half teaspoon of decaffeinated coffee subsequently poured into a styrofoam cup. Three tablets were crushed and dissolved with one-half teaspoon of 99.7% decaffeinated coffee and warm water for a 300 mg of caffeine solution to be used in the study. Six tablets were used in making the 600 mg of caffeine solution, and a teaspoon of baking soda was mixed with one-half teaspoon of decaffeinated coffee and warm water to represent the 0 mg control solution. The number drawn by the subjects and placed on the individual forms

represented one of the following assigned groups: 0 mg, 300 mg, or 600 mg of caffeine. Each subject had a one-hour period between the time of ingestion of the solution and the post-test. The procedure followed the double blind format.

Testing Instructions

The subjects were administered three tests for the two muscle groups, knee extensors and flexors, on the dominant side. The pre-test series occurred before ingestion of a testing solution and the post-test occurred sixty minutes after ingestion of the solution. Upon entering the test area, the subjects were seated and strapped into the Cybex testing unit. After all the initial information, including name and bodyweight, the computer was set accordingly. Both the pre-test and the post-test included three repetitions at 75 degrees per second, three repetitions at 180 degrees per second, and fifteen repetitions at 300 degrees per second.

Following the setting of the Cybex testing equipment, all the subjects were given the following specific instructions subsequent to testing:

> You will be tested on the Cybex II+ in three ways. First you will be asked to make three contractions of the upper leg muscles at a speed of 75 degrees per second. After a three minute recovery period, you will be asked to repeat the

contractions at 180 degrees per second. Following another recovery period, you will finally be asked to do fifteen repetitions at a speed of 300 degrees per second.

The following instructions were given to the subjects during the actual test:

The first test will involve three repetitions at 75 degrees per second. First you will have three practice repetitions to get a feel for the speed. Ready? Go. Now the following contractions will be the test. Please give your full effort. Ready-Begin. Now you will do the same for the next test. Remember the first three repetitions at 180 degrees per second will be practice. Ready? Go. Now the following contractions will be the test. Remember once again to give your full effort throughout the test. Ready-Begin. In this next test, you will be doing a series of fifteen repetitions at a rate of 300 degrees per second. You will be given a trial test of five repetitions to familiarize you with the speed. Ready? Go. Now you will do the fifteen repetitions at that speed. Remember to work for the full fifteen repetitions; do not let up when you feel tired. Really push yourself. Ready-Begin.

The following instructions were given to the subjects during the break between the two series of tests:

> You will now be asked to drink a solution. After drinking the solution you will remain here for sixty minutes, after which time you will repeat the identical test which you just finished. After each swallow, please use the tongue depressor provided and agitate the solution to assure complete dissolution. Be sure you drink all the solution.

Organization of the Data for Treatment

Torque tests were administered to all subjects while in a sitting position. All measurements on the upper leg involved extension and flexion at the knee joint, through contraction of the quadricep and the hamstring muscle groups, respectively.

The torque tests involved three voluntary maximal contractions through the full range of motion. For each test, peak torque degree where peak torque occurred, ratio of peak torque to bodyweight, and peak torque at two alternative angles 30 degrees and 70 degrees determined by normative data findings for peak torque at that joint were given. In addition, the fifteen repetition tests at 300 degrees per second yielded further flexion and extension ratio at peak torque.

All the information was calculated, printed, and accompanied by a foot pound graph by the Cybex Data Reduction Computer. Analysis of data in this study was handled through the statistical means of analysis of variance, using a Newman-Keuls post-test procedure in the event of significance. A one-way analysis of variance was performed on the pre-test data, before caffeine ingestion, to insure that the pre-test results did not have a significant inter-group variance. The level of significance to be tested was set at .05.

Permission and approval for this study has been sought from and granted by the Institutional Review Board.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

This chapter, which presents the data analysis for this investigation, has been divided into six parts: 1) Peak Torque at 75 degrees per second, 2) Peak Torque at 180 degrees per second, 3) Peak Torque at 300 degrees per second, 4) Ratio of Peak Torque and Bodyweight at 75 degrees per second, 5) Ratio of Peak Torque and Bodyweight at 180 degrees per second, and 6) Ratio of Peak Torque and Bodyweight at 300 degrees per second. All the analyses of variance used the .05 level of significance.

Results

Peak Torque at 75 Degrees per Second

The analyses for peak torque at 75 degrees per second are presented in Table IV. The critical values for .05 level of significance are F ratios 3.08 to 3.77. During the initial phase and extension of the repetitions, the pre-test F ratio was .8752 between groups. The post-test F ratio was insignificant when compared to the critical values set for the level of significance tested. The secondary phase of the repetitions, flexion, the pre-test F

TABLE IV

PEAK TORQUE AT 75 DEGREES PER SECOND

Variable	Pre-Test				
Degrees of Speed	Sum of squares	Mean of squares	D.F.	F Ratio	F Prob
75° Extension					
Between Groups	1499.2000	749.6000	2	.5390	.5968
Within Groups	16689.2000	1390.7667	12		
Total	18188.4000		14		
75° Flexion					
Between Groups	4267.2000	2133.6000	2	1.3375	.2990
Within Groups	19142.8000	1595.2333	12		
Total	23410.0000		14		

Variable	Post-Test				
Degrees of Speed	Sum of squares	Mean of squares	D.F.	F Ratio	F Prob
75° Extension					
Between Groups	2225.2000	1112.6000	2	.8752	.4418
Within Groups	15254.8000	1271.2333	12		
Total	17480.0000		14		
75° Flexion					
Between Groups	1584.1333	792.0667	2	.4772	.6318
Within Groups	19917.6000	1659.8000	12		
Total	21501.7333		14		

ratio was 1.3375 and the post-test F ratio was .4772. The post-test F ratio was insignificant when compared to the critical values set for the level of significance tested.

Peak Torque at 180 Degrees per Second

The analyses for peak torque at 180 degrees per second are presented in Table V. The critical values for .05 level of significance are F ratios of 3.08 to 3.77. During the extension phase at 180 degrees per second, the pre-test F ratio was 1.0989 and the post-test F ratio was 1.4294. The post-test F ratio was insignificant when compared to the critical values set for the level of significance tested. During the flexion phase at 180 degrees per second, the pre-test F ratio was .3770 and the post-test F ratio was .3326. The post-test F ratio was insignificant when compared to the critical values set for the level being tested.

Peak Torque at 300 Degrees per Second

The analyses for peak torque at 300 degrees per second are presented in Table VI. The critical values for .05 level of significance are F ratios of 3.08 to 3.77. During the extension phase at 300 degrees per second, the pre-test F ratio was .7756 and the post-test F ratio was 1.7386. The post-test F ratio was insignificant when compared to the critical values set for the level of significance tested. However, the post-test F ratio does show the sin-

TABLE V

PEAK TORQUE AT 180 DEGREES PER SECOND

Variable		Pre-Test			
Degrees of Speed	Sum of squares	Mean of squares	D.F.	F Ratio	F Prob
180° Extension					
Between Groups	2792.1333	1396.0667	2	1.0989	.3645
Within Groups	15244.8000	1270.4000	12		
Total	18036.9333		14		
180° Flexion					
Between Groups	1347.7333	673.8667	2	.3770	.6938
Within Groups	21449.2000	1787.4333	12		
Total	22796.9333		14		
Variable		**Post-Test**			
Degrees of Speed	Sum of squares	Mean of squares	D.F.	F Ratio	F Prob
180° Extension					
Between Groups	2688.9333	1344.4667	2	1.4294	.2774
Within Groups	11286.8000	940.5667	12		
Total	13975.7333		14		
180° Flexion					
Between Groups	1188.4000	594.2000	2	.3326	.7235
Within Groups	21439.6000	1786.6333	12		
Total	22628.0000		14		

TABLE VI

PEAK TORQUE AT 300 DEGREES PER SECOND

Variable		Pre-Test			
Degrees of Speed	Sum of squares	Mean of squares	D.F.	F Ratio	F Prob
300° Extension					
Between Groups	1464.9333	732.4667	2	.7756	.4822
Within Groups	11332.0000	944.3333	12		
Total	12796.9333		14		
300° Flexion					
Between Groups	1578.5333	789.4667	2	.6415	.5436
Within Groups	14763.2000	1230.2667	12		
Total	16341.7333		14		

Variable		Post-Test			
Degrees of Speed	Sum of squares	Mean of squares	D.F.	F Ratio	F Prob
300° Extension					
Between Groups	2376.4000	1188.2000	2	1.7386	.2172
Within Groups	8201.2000	683.4333	12		
Total	10577.6000		14		
300° Flexion					
Between Groups	1638.9333	819.4667	2	.7238	.5049
Within Groups	13586.8000	1132.2333	12		
Total	15225.7333		14		

gle largest increase from pre-test to post-test level during the peak torque portion of this study. This increase, although insignificant, may indicate the possibility that the treatment had an effect on the subjects being tested. During the flexion phase at 300 degrees per second, the pre-test F ratio was .6415 and the post-test F ratio was .7238. The post-test F ratio was insignificant when compared to the level of significance tested between groups.

Ratio of Peak Torque and Bodyweight at 75 Degrees per Second

The analyses for the ratio of peak torque and bodyweight at 75 degrees per second are presented in Table VII. The critical values for the .05 level of significance are F ratios of 3.12 to 3.81. During the extension phase at 75 degrees per second, the pre-test F ratio was .2032 and the post-test F ratio was .2513 between groups. The post-test F ratio was insignificant when compared to the critical values set for the level of significance tested. During the flexion phase at 75 degrees per second, the pre-test F ratio was .2532 and the post-test F ratio was .1891 between groups. The post-test F ratio was insignificant when compared to the critical values set for the level of significance tested.

TABLE VII

RATIO OF PEAK TORQUE AND BODYWEIGHT
AT 75° PER SECOND

Variable	Pre-Test				
	Sum of Squares	Mean of Squares	D.F.	F Ratio	F Prob
Extension at 75°/per sec					
Between Groups	508.9286	254.4643	2	.2032	.8191
Within Groups	13774.0000	1252.1818	11		
Total	14282.9286		13		
Flexion at 75°/per sec					
Between Groups	1388.2143	694.1071	2	.2532	.7807
Within Groups	30151.0000	2741.0000	11		
Total	31539.2143		13		

Variable	Post-Test				
	Sum of Squares	Mean of Squares	D.F.	F Ratio	F Prob
Extension at 75°/per sec					
Between Groups	390.0000	195.0000	2	.2513	.7821
Within Groups	8536.0000	776.0000	11		
Total	8926.0000		13		
Flexion at 75°/per sec					
Between Groups	649.0786	324.5393	2	.1891	.8304
Within Groups	18880.3500	1716.3955	11		
Total	19529.4286		13		

Ratio of Peak Torque and Bodyweight at 180 Degrees per Second

The analyses for the ratio of peak torque and bodyweight at 180 degrees per second are presented in Table VIII. The critical values for .05 level of significance are F ratios of 3.12 to 3.81. During the extension phase at 180 degrees per second, the pre-test F ratio was .1640 and the post-test F ratio was .5054 between groups. The post-test F ratio was insignificant when compared to the critical values set for the level of significance tested. During the flexion phase at 180 degrees per second, the pre-test F ratio was .1738 and the post-test F ratio was .0406 between groups. The post-test F ratio was insignificant when compared to the critical values set for the level of significance tested.

Ratio of Peak Torque and Bodyweight at 300 Degrees per Second

The analyses for the ratio of peak torque and bodyweight at 300 degrees per second are presented in Table IX. The critical values set for .05 level of significance are F ratios of 3.12 to 3.81. During the extension phase at 300 degrees per second, the pre-test F ratio was .4539 and the post-test F ratio was .9472 between groups. The post-test F ratio was insignificant when compared to the critical values set for the level of significance tested. During the flexion phase at 300 degrees per second, the

TABLE VIII

RATIO OF PEAK TORQUE AND BODYWEIGHT
AT 180° PER SECOND

Variable	Pre-Test				
	Sum of Squares	Mean of Squares	D.F.	F Ratio	F Prob
Extension at 180°/per sec					
Between Groups	227.2071	113.6036	2	.1640	.8508
Within Groups	7619.1500	692.6500	11		
Total	7846.3571		13		
Flexion at 180°/per sec					
Between Groups	523.2500	261.6250	2	.1738	.8427
Within Groups	16554.7500	1504.9773	11		
Total	17078.0000		13		

Variable	Post-Test				
	Sum of Squares	Mean of Squares	D.F.	F Ratio	F Prob
Extension at 180°/per sec					
Between Groups	656.1786	328.0893	2	.5054	.6166
Within Groups	7140.7500	649.1591	11		
Total	7796.9286		13		
Flexion at 180°/per sec					
Between Groups	130.0643	65.0321	2	.0406	.9603
Within Groups	17613.1500	1601.1955	11		
Total	17743.2143		13		

TABLE IX

RATIO OF PEAK TORQUE AND BODYWEIGHT
AT 300° PER SECOND

Variable	Pre-Test				
	Sum of Squares	Mean of Squares	D.F.	F Ratio	F Prob
Extension at 300°/per sec					
Between Groups	790.9071	395.4536	2	.4539	.6465
Within Groups	9583.9500	871.2682	11		
Total	10374.8571		13		
Flexion at 300°/per sec					
Between Groups	825.7000	412.8500	2	.3967	.6818
Within Groups	11447.8000	1040.7091	11		
Total	12273.5000		13		

Variable	Post-Test				
	Sum of Squares	Mean of Squares	D.F.	F Ratio	F Prob
Extension at 300°/per sec					
Between Groups	976.8571	488.4286	2	.9472	.4173
Within Groups	9583.9500	515.6364	11		
Total	6648.8571		13		
Flexion at 300°/per sec					
Between Groups	506.9571	253.4786	2	.4489	.6495
Within Groups	6211.4000	564.6727	11		
Total	6718.3571		13		

pre-test F ratio was .3967 and the post-test F ratio was .4489 between groups. The post-test F ratio was insignificant when compared to the critical values set for the level of significance tested.

Discussion of Results

This section has been organized to include a general discussion of the results obtained in this study. An analysis of variance was performed on all subjects. At speeds of 75 degrees per second, 180 degrees per second and 300 degrees per second, peak torque and a ratio of peak torque and bodyweight pre-test and post-test were compared to each other within the parameters of this study. The results of these analyses indicate that there was no significant difference in peak torque at 75 degrees per second, 180 degrees per second, 300 degrees per second, and no significant difference in a ratio of peak torque and body weight at the same speeds.

There are currently only two studies pertaining to the effects of varying doses of caffeine on muscle strength. One study conducted by Lopes et al. (1983) on five adults investigated the effects of caffeine on the adductor pollicis muscle. Utilizing electrical stimulation, Lopes et al. concluded that caffeine had a direct effect on skeletal muscle contractile properties by increasing tension in the muscle. However, when the subjects were measured using maximal voluntary contraction, Lopes et al.

concluded there were no significant differences between the placebo and caffeine. The similarity between the present study and Lopes et al. is that all the subjects were untrained, and both studies found no significant differences in the effects of caffeine on muscle strength produced by voluntary contraction.

In an almost identical study, Bond et al. studied twelve male intercollegiate track sprinters. Unlike the present study, Bond's subjects were all trained. Using the same Cybex II Isokinetic testing equipment used in the present study, Bond et al. administered 5mg/kg of caffeine. After ingestion of the caffeine or placebo capsules, the subjects rested in a sitting position for sixty minutes to allow for peak absorption. At the end of this period a venous blood sample was taken, after which the test began. During the test, subjects were required to perform six maximal voluntary contractions of the knee extensors and knee flexors of the dominant leg, at speeds of 30 degrees per second, 150 degrees per second and 300 degrees per second. Bond used a cross over design. Following the study, Bond et al. concluded that the results showed no significant effects of caffeine ingestion on knee extension and knee flexion force exerted at 30 degrees, 150 degrees, and 300 degrees degrees per second. These findings are in agreement with Lopes et al.

The present study was similar to Bond's in many facets: both incorporated the Cybex II testing equipment,

both tested three speeds of contraction ranging from low to high, and both studies tested the knee extensors and flexors. The two major differences that merit noting are 1) Bond et al. used trained track subjects, and 2) Bond et al. administered caffeine according to bodyweight, but in the present study two groups were administered 300mg and 600mg of caffeine regardless of bodyweight.

The present study is in agreement with Lopes et al. (1983) and Bond et al. (1986), in which both investigators reported at the conclusion of their studies that caffeine has no significant effect on muscle strength performed by voluntary contraction. It should be pointed out again, however, that Lopes et al. did obtain tension development during low stimulation.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

Summary

Fifteen university students were tested for the effects of caffeine under the following conditions: 0 mg, 300 mg, and 600 mg of caffeine on peak torque for knee extension and knee flexion at 75 degrees per second, 180 degrees per second, and 300 degrees per second, and ratio of peak torque and bodyweight for knee extension and knee flexion at 75 degrees per second, 180 degrees per second, and 300 degrees per second. All the tests were evaluated in two separate phases: the extension phase and the flexion phase. After a pre-test solution of either 0 mg, 300 mg, or 600 mg of caffeine was ingested, the subjects rested sixty-minutes before the post-test was administered.

Under the prescribed dosages results indicated that peak torque at 75 degrees per second, 180 degrees per second and 300 degrees per second resulted in no significant differences from pre-test to post-test. The ratio of peak torque to bodyweight at 75 degrees per second, 180 degrees per second and 300 degrees per second demonstrated no significant differences from pre-test to post-test.

All the differences were insignificant at the .05 level of significance. The table ranges for .05 level of significance were F ratios of 3.08 to 3.77 for the peak torque at 75 degrees per second, 180 degrees per second and 300 degrees per second. The table ranges for .05 level of significance were F ratios of 3.12 to 3.88 for the ratio of peak torque and bodyweight at 75 degrees per second, 180 degrees per second and 300 degrees per second.

Conclusions

From the findings of this investigation the following conclusions can be made concerning the fifteen university students who participated in the study:

1. The dosages of caffeine administered did not significantly increase peak torque at 75 degrees per second.

2. The dosages of caffeine administered did not significantly increase peak torque at 180 degrees per second.

3. The dosages of caffeine administered did not significantly increase peak torque at 300 degrees per second.

4. The dosages of caffeine administered did not significantly increase the ratio of peak torque to bodyweight at 75 degrees per second.

5. The dosages of caffeine administered did not significantly increase the ratio of peak torque to bodyweight at 180 degrees per second.

6. The dosages of caffeine administered did not significantly increase the ratio of peak torque to bodyweight at 300 degrees per second.

Recommendations for Further Study

Due to results presented in the review of literature as well as in the results of this study, further investigations need to be conducted concerning the effects of caffeine on exercise performance. The following studies are therefore recommended:

1. Peak torque studies using a higher dosage of caffeine on acclimated intercollegiate athletes.

2. Peak torque studies using a higher dosage of caffeine with a slower speed of degrees per second on the Cybex II+.

3. An evaluation of the effects of caffeine in higher dosages on the endurance of intercollegiate distance runners.

4. An evaluation of the effects of caffeine in higher dosages on watts of power at a slower speed of degrees per second on the Cybex II+.

5. An evaluation of the effects of caffeine in higher dosages on the ratio of peak torque and bodyweight on acclimated intercollegiate athletes.

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APPENDIX A

INFORMED CONSENT CAFFEINE

MUSCLE STRENGTH AND FATIGUE CURVES

I,_____, the undersigned, understand
(name)
that I am participating in a research study designed to measure the effect of caffeine ingestion on reaction and movement times. The study will involve the following procedures:

1. Maximal strength measured by Cybex II requiring maximum effort (2 trials)
2. Fatigue curves measured by requiring sustained effort (forward arm or leg movement).
3. Ingestion of 300 mg caffeine or 600 mg caffeine or a placebo. REPEAT of steps 1 and 2 one hour later.

The entire test should require no more than 1.5 hours and presents the following possible benefits to me:

1. Learn my maximal strength and fatigue curves of specified limb movement.
2. Understand the effect of caffeine on maximal strength and fatigue curves.

I also understand that the ingestion of caffeine presents the following possible symptoms/reactions:

1. Temporary nervousness and anxiety.
2. Elevated heart rate and blood pressure.
3. Decreased hand stability.
4. Increased cardiac irritability.
5. Increased intestinal motility.

By affixing my signature below, I hereby release Oklahoma State University, the School of Health, Physical Education and Leisure Services, Health and Fitness Center, and the investigator from any liability of repercussion.

_____
Signed

_____
Printed Name

_____
Witness

APPENDIX B

CAFFEINE RESEARCH QUESTIONNAIRE

Name_____ Age_____ Sex_____

Height_____ Weight_____ BF_____

BP(pre)_____/_____

HR(pre)_____b/min

BP(pre)_____/_____

HR(post)_____b/min

Caffeine Consumption History

Coffee cups/day_____ /wk_____

Cokes, DP, MT. Dew/day_____ /wk_____

Tea cups or glasses/day_____ /wk_____

Other-explain_____

How does caffeine effect you_____

_____.

Release form_____ yes/no

Please stop here if you have not signed release.

Have you fasted (w/o food) for the last 8 hours?

_____ yes/no

Last meal was_____ hours ago.

Are you presently under any medication?_____

Are you taking oral contraceptive or are you pregnant?

_____ oral

_____ pregnant

Last caffeine consumed_____ hours ago.

In the form of _____.

_____Time substance was taken.

_____Time of post-test

Group #

VITA 2

Kelly Don Drake

Candidate for the Degree of

Master of Science

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