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The Effect of Caffeine on Reaction Time, Hand Steadiness, and Certain Physiological Variables

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THE EFFECT OF CAFFEINE ON REACTION TIME, HAND STEADINESS, AND
CERTAIN PHYSIOLOGICAL VARIABLES

by

Amy K. Ryan

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Health, Physical Education,
and Recreation

Western Michigan University
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Amy K. Ryan

THE EFFECT OF CAFFEINE ON REACTION TIME, HAND STEADINESS, AND CERTAIN PHYSIOLOGICAL VARIABLES

Amy K. Ryan, M.A.

Western Michigan University, 1998

The problem of this study was to analyze the effect of caffeine on heart rate, blood pressure, reaction time, and hand steadiness. Subjects ($N = 20$) were classified as high-caffeine users or low-caffeine users. Heart rate, blood pressure, reaction time, and hand steadiness were measured. Subjects then consumed 24 oz of coffee containing 345 mg of caffeine in a 5-min period. Dependent variables were measured again at 30, 60, and 90 min after caffeine administration. Significant differences were found among test time means for every dependent variable except hand steadiness. No difference was found between the high-caffeine-use group and the low-caffeine-use group for heart rate, blood pressure, or hand steadiness. The researcher concluded that caffeine (a) did not increase heart rate, (b) increased systolic blood pressure 60 min after caffeine intake, (c) increased diastolic blood pressure at 30 and 60 min after caffeine intake, (d) decreased reaction time for the high-caffeine-use group, and (e) had no effect on hand steadiness. Recommendations for further study include designing the study to measure baseline heart rate and blood pressure prior to caffeine administration and using a balanced placebo design to see if regular caffeine users respond due to caffeine or to expectancy.

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CHAPTER I

INTRODUCTION

Many people count on a cup of coffee to wake them up in the morning. Among adults, coffee has become widely popular due to the drug caffeine; coffee is the largest source of caffeine consumption in America. Caffeine's stimulating effect can make people think more clearly and feel less tired; this is because caffeine ingestion causes heart and metabolic rates to rise, producing a feeling of alertness. There are also many negative health consequences related to caffeine, such as anxiety and sleep disturbances. Despite the health risk, caffeine remains one of the world's most widely used drugs.

Caffeine affects each individual differently. Factors such as dosage and past usage contribute to how the body responds to caffeine. Whatever the response, the effect caffeine has on the body takes place shortly after ingestion and is relatively short-lived. Once caffeine has been metabolized, the effect is gone. Because everyone responds to caffeine differently, there are no specific guidelines for caffeine use. Studies show, however, that greater ingestion does not result in greater stimulation; high doses of caffeine may even have a depressant effect. As caffeine continues to be the world's most widely used drug, individuals who use caffeine should be aware of its effect on all parts of the body and pay attention to how it interacts with their own chemistry.

Statement of the Problem

This study was designed to analyze the effect of caffeine, in the form of coffee, on reaction time, hand steadiness, blood pressure, and heart rate. Two groups, high caffeine intake and low caffeine intake, were tested.

Need for the Study

As caffeine intake continues to increase among adults, there is a need for more research concerning the effect caffeine has on the body. Negative health consequences associated with caffeine include insomnia, feelings of nervousness, cardiac arrhythmias, and elevated cholesterol. Headache is just one of the many symptoms associated with caffeine withdrawal. Information on the health risks caused by caffeine use has prompted many adults to reduce their caffeine intake, but at least one third of all Americans still consume about 10 oz of coffee daily. Caffeine is a drug that, unlike nicotine or alcohol, carries no warning label. Until warnings are put on highly caffeinated products, more research needs to be done on the widespread effects caffeine has on the body.

Delimitations

This study was delimited to the following:

1. Subjects were 20 male and female volunteers between the ages of 18 and 30 years from the Kalamazoo, MI area.
2. Subjects were free of cardiovascular disease and hypertension, were not on caffeine-restricted diets, and were not pregnant.
3. Subjects were administered 345 mg of caffeine in the form of coffee.

4. Reaction time was tested on a Visual Choice Reaction Time apparatus, model 63035, Lafayette Instrument Co., Lafayette, IN.

5. Hand steadiness was measured on a Groove Type Steadiness Tester, model 32010, Lafayette Instrument Co., Lafayette, IN.

6. Heart rate was measured on a Polar Heart Rate Monitor, model 1901201, Polar Electro Inc., Port Washington, NY.

7. Blood pressure was measured with a 300 mmHg manometer, model 0320, and a calibrated V-Lok cuff, W. A. Baum Co., Inc., Copiague, NY; also used was a Mabis Elite Sprague Rappaport-Type Stethoscope, model 90-414-010, Mabis Healthcare, Inc., Lake Forest, IL.

8. Dependent variables were measured during a pretest and three posttests. Posttests occurred 30, 60, and 90 min after caffeine consumption.

9. Subjects performed 5 trials for each motor learning task for the pretest and posttests.

10. Subjects were classified as high-caffeine-users, requiring a weekly intake of more than 1,000 mg of caffeine, or low-caffeine-users, defined by a weekly intake of less than 200 mg of caffeine.

Limitations

This study was limited by the following factors:

1. Subjects were representative of high-caffeine and low-caffeine consumers; the high-use and low-use groups formed may not have been an accurate sample of the high-caffeine and low-caffeine intake population.

2. The sample size was small and therefore may be biased.

Assumptions

The following assumptions were made for the study:

1. Subjects were accurate with their reported caffeine intake.
2. The subjects were familiar with the motor learning tasks and therefore were not learning.
3. Subjects refrained from caffeine intake at least 2 hours prior to the study.

Research Hypotheses

The study investigated the following research hypotheses:

1. During the posttests, blood pressure was higher for the low-caffeine group than for the high-caffeine group.
2. During the posttests, heart rate was higher for the low-caffeine group than for the high-caffeine group.
3. During the posttests, reaction time was slower for the high-caffeine group than for the low-caffeine group.
4. During the posttests, hand steadiness scores were lower for the low-caffeine group than for the high-caffeine group.
5. The pretest heart rates were lower than the posttest heart rates.
6. The pretest blood pressures were lower than the posttest blood pressures.
7. The pretest reaction times were slower than the posttest reaction times.
8. The pretest steadiness tests were better than the posttest steadiness tests.
9. Blood pressure for the 90-min posttest will be less than for the 30-min or 60-min posttests.
10. Heart rates for the 90-min posttest will be less than for the 30-min or 60-min post-tests.

11. Reaction time will be slower for the 90-min posttest than for the 30-min or 60-min posttests.
12. Steadiness will be less for the 30-min and 60-min posttests than for the 90-min posttest.
13. Blood pressures for the 30-min and 60-min posttests will not be different.
14. Heart rates for the 30-min and 60-min posttests will not be different.
15. Reaction times for the 30-min and 60-min posttests will not be different.
16. Steadiness for the 30-min and 60-min posttests will not be different.

Definition of Terms

The following terms were defined for the study:

1. Reaction Time: the time elapsed between stimulation and the beginning of the reaction to it (Nieman, 1990).
2. Movement Time: the time period between reaction to a stimulus and completion of movement (Magill, 1993).
3. Total Reaction Time: reaction time plus movement time (Magill, 1993).

CHAPTER II

REVIEW OF RELATED LITERATURE

Caffeine is the most popular and widely consumed drug in the world (Julien, 1995). Coffee accounts for 75% of all the caffeine consumed in the United States (Johnson-Greene, 1988). Julien stated that 80% of adults drink between three and five cups of coffee every day. Caffeine is widespread, socially acceptable, inexpensive, and popular for its ability to reduce fatigue and produce feelings of alertness.

Caffeine's stimulating effect makes people feel they can think more clearly. Caffeine increases activity in the central nervous system, causing people to feel more energetic. The physiological effects of caffeine vary from person to person, and factors such as dosage and past usage will determine how this drug affects an individual. Large doses of caffeine can have a depressant effect, reducing the body's ability to function (Kleiner, 1995). Overuse of caffeine can result in a syndrome called caffeinism, characterized by symptoms such as anxiety, insomnia, hypertension, and cardiac arrhythmias (Julien, 1995). Despite any health risks, caffeine remains one of the most commonly used stimulants in the world (Lotshaw, Bradley, & Brooks, 1996).

Mechanism of Action

Caffeine works in the central nervous system and in fat cells by binding to adenosine receptors and increasing intracellular concentrations of cyclic adenosine monophosphate (Robergs & Roberts, 1997). Adenosine's job is to act on specific receptors on the surface of cells to depress central neurons and inhibit the release of neurotransmitters; the blockade of the receptors by caffeine causes brain activity to

speed up. This is due to the release of the neurotransmitters usually quieted by adenosine. In short, caffeine plugs adenosine receptors, blocking their normal ability to slow the brain down (Braun, 1996).

The cortex is the first of the brain stem structures to be affected. The result of this cerebral cortical stimulation is increased mental awareness, clearer flow of thought, wakefulness, and restlessness; fatigue is reduced and the need for sleep is delayed. Caffeine has a slight stimulating action on the heart, dilating the coronary arteries. The ingestion of caffeine also constricts the blood vessels in the brain, decreasing blood flow, which can relieve headaches (Julien, 1995).

Taken orally, caffeine is quickly absorbed; significant blood levels of caffeine are reached in 30 to 45 min (Julien, 1995). In addition to directly stimulating the central nervous system, caffeine is absorbed rapidly from the stomach and small intestine and crosses the blood/brain barrier quite readily (Sullivan, 1997). Caffeine levels are elevated in the blood as soon as 15 min and peak at 60 min (Howley & Powers, 1990). An individual's metabolism, body temperature, heart rate, and blood pressure may increase. Caffeine is freely and equally distributed throughout all the water in the body (Julien, 1995). Caffeine is then diluted by the body water, and the physiological response is proportional to the concentration in the body water. There is a natural variability in how people respond to caffeine, and chronic users are less responsive than abstainers (Howley & Powers, 1990).

Side Effects

One of the most well known side effects from caffeine use is its stimulation of urination and defecation. The kidneys have many adenosine receptors; adenosine helps regulate the balance between blood flow and urine output. When caffeine blocks these receptors, it causes blood vessels to dilate, increasing the filtration rate and producing

more urine. The colon also has many adenosine receptors; adenosine helps control the balance between relaxation and contraction of smooth muscles used to move waste. Caffeine causes constriction in the colon by blocking relaxation messages usually sent by adenosine. This causes smooth muscle to contract more easily, making caffeine act as a laxative (Braun, 1996).

Some people complain of stomach upset, nervousness, and irritability from the stimulating effects of caffeine (Kleiner, 1995). Caffeine can affect psychomotor coordination, sleep, mood, behavior, and cognition. Caffeine increases the speed at which a person can tap a button, but it may impair fine motor coordination (Eichner, 1986). Tasks that involve delicate muscular coordination and accurate timing may be adversely affected (Julien, 1995). Caffeine increases reading speed but not short-term memory. Coffee before bed increases sleep latency, decreases total sleep time, increases spontaneous awakenings, and worsens perceived quality of sleep. There is individual variation with sleep response; heavy coffee users may become tolerant to caffeine's sleep altering actions. Heavy users also report pleasant stimulation and alertness from caffeine use, yet nonusers report unpleasant stimulation, nervousness, or anxiety (Eichner, 1986).

There is growing evidence caffeine may be a contributing factor in the development of a number of diseases; conditions such as cardiovascular disease and birth defects are now being linked to excess use of caffeine (Johnson-Greene, 1988). Studies have also linked caffeine with increased heart attacks and ulcers (Sullivan, 1997). Johnson-Greene also implicated the use of caffeine in cancer of the bladder, pancreas, and gastrointestinal tract. The intake of 500 to 600 mg of caffeine per day (approximately four to seven cups of coffee) is believed to represent a significant health risk (Johnson-Greene, 1988).

Tolerance and Withdrawal

There is a great variation in people's physical response to caffeine; it relaxes certain individuals yet makes others nervous and anxious. Habitual drinkers of caffeine have less difficulty sleeping than non drinkers at comparable caffeine blood levels (Julien, 1995). Many habitual drinkers of caffeine find they must increase their dose to achieve the desired degree of stimulation. Caffeine causes an increase in brain activity, and the brain responds by trying to reduce its activity so it can maintain a setpoint; this flexible response to caffeine's effect is called tolerance. Caffeine blocks adenosine receptors which triggers the creation of more receptors; this is called up-regulation, and it may be responsible for tolerance to caffeine (Braun, 1996).

Humans generally become tolerant to a given dose of caffeine in a week to 12 days. Tolerance to caffeine is complete; tolerant users experience little, if any, stimulation by their usual dose. One theory as to why caffeine remains so popular despite essentially no stimulation after tolerance is that some parts of the brain may not become tolerant (Braun, 1996). Another theory to explain the continual consumption of caffeine is the avoidance of withdrawal. Chronic use of caffeine is often associated with habituation and tolerance, and discontinuation may produce withdrawal symptoms (Julien, 1995).

Stable circulating levels of caffeine drop when an individual abstains after building a tolerance. This causes the brain's balance of neurotransmitters and receptors to change radically. The result is withdrawal, physical and psychological symptoms that can range from undetectable to intensely unpleasant. Most regular consumers of caffeine are in the first stages of withdrawal when they wake up in the morning; for this reason, caffeine users generally feel more tired, irritable, and groggy in the morning. If morning intake is skipped, a headache is likely, but drinking caffeine quickly alleviates

withdrawal symptoms. The most common symptom of withdrawal is headache. Braun listed other typical symptoms as depression, fatigue, lethargy, irritability, increased muscle tension, nausea, and vomiting. Responses vary, and even heavy caffeine consumers may not experience withdrawal. Symptoms begin within 12 hours to 1 day after the last use and peak anywhere from 20 hours to 2 days after caffeine consumption stops. After 48 hours symptoms tend to taper off, but it usually takes a full week for the body to return to normal (Braun, 1996).

Uses for Caffeine

Diet Aid

The active ingredient in most over-the-counter diet aids used to be caffeine. In 1991, the Food and Drug Administration banned caffeine from all diet aids, ruling that it neither suppresses appetite nor causes weight loss. Caffeine does have the ability to release fat and break it down into useful fatty acids. This could benefit athletic people, because frequent exercise enable the muscles to burn the liberated fatty acids. For more sedentary individuals, the fatty acids released from caffeine are likely to be reconverted to fat once caffeine levels drop; therefore, caffeine is not a fat burner. Studies have shown that caffeine does raise the basal metabolic rate, which results in a small increase in body temperature and caloric consumption. The average increase in caloric consumption is between 50 to 100 calories; this may be significant to a perfectly uniform diet, but any individual's diet is usually far from uniform (Braun, 1996).

Ergogenic Aid

Studies have shown caffeine can be effective in increasing total work time, making it an ergogenic aid. The mobilization of fuel for muscular work is the primary

means by which caffeine acts as an ergogenic aid (Howley & Powers, 1990). Caffeine causes an increase in the use of fatty acids by releasing fat stored in cells and breaking it down into smaller fatty acid chains that the body burns as fuel. Caffeine's ability to liberate some of the fuel supply stored in fat may be beneficial to athletic performance (Braun, 1996). Also, mobilization of free fatty acids by caffeine may have a glycogen-sparing effect in that it enables more fat to be used as fuel; glycogen-sparing in turn reduces muscle fatigue (Foss & Keteyian, 1998). Some studies showed physiological change with caffeine doses as low as 5 to 7 mg/kg; doses up to 15 mg/kg may be needed to see an increase in fat metabolism (Howley & Powers, 1990). The shift in fuel use caused by caffeine appears to enhance endurance performance (Van Handel, 1980). The ergogenic effect is dose dependent and varies with the type of individual (Howley & Powers, 1990).

CHAPTER III

METHODOLOGY

The problem of the study was to analyze the effect of caffeine on reaction time, hand steadiness, heart rate, and blood pressure. These variables were measured before and after caffeine intake. Prior to caffeine intake, 5 trials were performed for both reaction time and hand steadiness. After the administration of 345 mg of caffeine in the form of Folger's single serving packets, reaction time and accuracy were each tested five times at three posttest times: 30, 60, and 90 min after caffeine ingestion. Heart rate and blood pressure were recorded at the start of each posttest. This chapter includes the following procedural steps: (a) selection of subjects, (b) research design, (c) instrumentation, (d) testing procedures, and (e) treatment of data.

Selection of Subjects

The subjects were 20 male and female volunteers, ages 17 to 30 years. Potential subjects were screened for cardiovascular disease, hypertension, and caffeine-restricted diets (see Screening Form, Appendix A). Individuals with diagnosed heart problems, diagnosed hypertension, or a physician's order to restrict caffeine were not eligible for participation in the study. In addition, females who indicated they were pregnant were not eligible for the study. The subjects gave written consent prior to participation (see Consent Form, Appendix B). Subjects were screened for caffeine use and were grouped according to caffeine intake. The first 10 volunteers who indicated they regularly consumed more than 1000 mg of caffeine per week were put into a

high-caffeine-use group, and the first 10 volunteers who indicated they consumed less than 200 mg per week were put into a low-caffeine-use group. Subjects' rights were protected as required by the Human Subjects Institutional Review Board (see HSIRB approval letter, Appendix C). –

Research Design

Both individuals who depend on caffeine and those who restrict caffeine from their diets were actively recruited. Subjects were selected based on their self-reported caffeine intake. If they reported consuming less than 200 mg of caffeine (less than two cups of coffee) per week, they were classified as low-caffeine-users. If they reported consuming 1000 mg or more of caffeine per week, they were classified as high-caffeine-users. Each group consisted of 10 subjects.

Four dependent variables were measured: (1) reaction time, (2) hand steadiness, (3) heart rate, and (4) blood pressure. These variables were measured before caffeine administration and at 30, 60, and 90 min after caffeine administration. Five trials were performed for the motor learning tasks in both the pretest and posttests. The 5 trials were administered to obtain a more representative true score for individuals on each motor learning test. A subject's score for each of the motor learning tasks was obtained by discarding the best and worst trials and calculating the mean of the remaining 3 trials.

Instrumentation and Dependent Variables

The following equipment was used to collect data for this study:

1. Visual Choice Reaction Time apparatus, model 63035, Lafayette Instrument Co., Lafayette, IN, was used to measure reaction time. Subjects were given a white light signal and were instructed to press a button as soon as they saw the light. The time

from the stimulus until they pressed the button was measured to the nearest thousandth second and served as the subject's score.

2. Groove Type Steadiness Tester, model 32010, Lafayette Instrument Co., Lafayette, IN, was used to measure hand steadiness. Subjects slid a metal stylus along a mirrored track with raised sides. The left side of the track contained a ruler marked in centimeters. The distance traveled by the stylus until one side of the track was contacted served as the subject's score.

3. Polar Heart Rate Monitor, model 1901201, Polar Electro Inc., Port Washington, NY, was used to measure heart rate. Subjects strapped the monitor just below the chest, and they placed the corresponding watch on their wrists to record heart rate in beats per minute (bpm). The average heart rate over 30 s was recorded as the subject's score.

4. A 300 mmHg manometer, model 0320, and Calibrated V-Lok Cuff, W. A. Baum Co., Inc., Copiague, NY; and a Mabis Elite Sprague Rappaport-Type Stethoscope, model 90-414-010, Mabis Healthcare, Inc., Lake Forest, IL, were used to measure blood pressure. Both the systolic and diastolic readings served as dependent variables for this study.

5. Folger's Aroma Roasted Coffee Singles, Folger's, Sherman, TX, were used as the source of caffeine. Each single serving packet contained 115 mg of caffeine.

Testing Procedures

All testing was completed in the Exercise Physiology Lab in the University Recreation Center at Western Michigan University. Prior to the study, subjects signed a consent form containing possible risks of the study. Subjects also filled out a screening form. Individuals with hypertension, heart problems, or caffeine-restricted diets, and

individuals who were pregnant were not selected to participate in the study. Each subject was given an identification number to be used for data collection (see Data Collection Sheet, Appendix D). Before testing, subjects were given 10 practice trials on the Visual Choice Reaction Time apparatus and 5 practice trials on the Groove Type Steadiness Tester. After practicing, a heart rate monitor was put on and subjects were given 5 min to relax.

After the rest period, a resting heart rate was measured. Heart rate was recorded every 5 s, and the average heart rate over 30 s served as the dependent variable. Next, a resting blood pressure was taken. Subjects were then tested on the Visual Choice Reaction Time apparatus. They were given a command of “ready” before the white light signal was activated. The time between the “ready” command and the introduction of the light was varied so subjects did not learn to anticipate the signal. The index finger of the dominant or preferred hand was positioned on an “X” marked at the base of the Visual Choice Reaction Time apparatus. Thus, the distance moved to extinguish the light was consistent among trials and among subjects. Upon seeing the white light, subjects depressed a button, and total reaction time (reaction time plus movement time) was measured to the nearest thousandth second. Five trials were run with a rest period of 30 s between trials. The highest and lowest of the 5 scores were eliminated, and the average of the three remaining scores was recorded as the subject’s score for reaction time.

After reaction time testing was completed, subjects were given a 2-min rest period. After 2 min, hand steadiness was tested on the Groove Type Steadiness Tester. Subjects ran a metal stylus along a mirrored track with raised sides until they touched a side. Subjects held the stylus at the first point of contact with either side; the left side of the track contained a ruler with which the point of contact was measured to the nearest tenth centimeter. The distance traveled until the stylus hit a side served as the subject’s

score. Five trials were run with a rest period of 60 s between trials. The highest and lowest scores were eliminated, and the average of the three remaining scores was recorded as the subject's score for hand steadiness.

After the pretest was complete, subjects were given a 345 mg dose of caffeine in the form of a 24 oz cup of coffee. A thermometer was used to make sure the temperature of the coffee was between 110° F and 120° F. Subjects were given 5 min to drink the coffee, then the first posttest began 30 min after the coffee was consumed. Posttests were also run at 60 and 90 min after caffeine consumption. Heart rate, blood pressure, reaction time, and accuracy were measured in each posttest following the same procedure used in the pretest.

Statistical Analysis

A split-plot factorial ANOVA design was calculated for each of the dependent variables: (a) heart rate, (b) systolic blood pressure, (c) diastolic blood pressure, (d) reaction time, and (e) hand steadiness. The grouping variable for the design was caffeine consumption, with two levels: (1) low, less than 200 mg of caffeine ingested per week; and (2) high, 200 mg or more of caffeine ingested per week. The research variable for the design was time, with four levels: a pretest and 3 posttest times (30, 60, and 90 min). A posteriori comparisons were calculated by using the Tukey HSD test or simple main effect test.

CHAPTER IV

RESULTS AND DISCUSSION

In this study, the researcher investigated the effects of caffeine on heart rate, blood pressure, reaction time, and hand steadiness. Because caffeine is the world's most popular stimulant, more research needs to be done on how it affects the body. The typical American drinks about two cups of coffee a day; coffee alone accounts for over half of the caffeine people consume. Researchers are just beginning to discover caffeine's link to several diseases. Because caffeine's effect varies with each individual, there is no dose that can be designated as safe for all people.

Results

Four dependent variables were measured: (1) heart rate, (2) blood pressure, (3) reaction time, and (4) hand steadiness. These variables were measured before caffeine administration and at 30, 60, and 90 min after caffeine administration. Subjects were classified as high-caffeine users (caffeine intake >1000 mg/week) or low-caffeine users (caffeine intake < 200 mg/week); each group was comprised of 10 subjects. Both male and female subjects participated in this study. The high-caffeine-use group consisted of 5 males and 5 females. The low-caffeine-use group consisted of 2 males and 8 females. A split-plot factorial ANOVA design was calculated for each of the dependent variables. A posteriori comparisons were calculated by using the Tukey HSD test or simple main effect test.

Heart Rate

Heart rate was measured by a Polar heart rate monitor; it was recorded before treatment and 30, 60, and 90 min after treatment. An ANOVA summary for heart rate is presented in Table 1. No difference was found between the heart rates of the subjects in the high-caffeine-use group, $\bar{M} = 69.4$ bpm, and the low-caffeine-use group, $\bar{M} = 69.1$ bpm, $F(1, 18) = 0.01$, $p = .94$. A significant difference was found among the test time means, $F(3, 54) = 8.31$, $p = .00$. The means for the pretest, 30-min, 60-min, and 90-min tests were 69.5 bpm, 70.2 bpm, 72.3 bpm, 65.1 bpm, respectively. The Tukey test, $HSD = 3.93$, $p < .05$, indicated the following significant differences between pairs of means: (a) the pretest mean was greater than the 90-min test mean, (b) the 30-min test mean was greater than the 90-min test mean, and (c) the 60-min test mean was greater than the 90-min test mean. The first-order interaction effect, Group x Tests, was not significant, $F(3, 54) = 0.18$, $p = .91$.

Table 1
ANOVA Summary Table for Heart Rate

Source	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>p</u>
Between Subjects					
Group (G)	1.80	1	1.80	0.01	.94
Error	6134.20	18	340.79		
Within Subjects					
Tests (T)	541.90	3	180.63	8.31	.00
G x T	11.90	3	3.97	0.18	.91
Error	1173.20	54	21.73		

Systolic Blood Pressure

Systolic blood pressure was recorded before treatment and 30, 60, and 90 min after treatment. An ANOVA summary for systolic blood pressure is presented in Table 2. No difference was found between the systolic pressures of the subjects in the high-caffeine-use group, $\bar{M} = 116.3$ mmHg, and the low-caffeine-use group, $\bar{M} = 111.5$ mmHg, $F(1, 18) = 0.56$, $p = .46$. A significant difference was found among test time means, $F(3, 54) = 4.22$, $p = .01$. The means for the pretest, 30-min, 60-min, and 90-min tests were 111.8 mmHg, 114.0 mmHg, 116.4 mmHg, and 113.4 mmHg, respectively. The Tukey test, $HSD = 3.50$, $p < .05$, indicated a significant difference between one mean pair: the 60-min test mean was greater than the pretest mean. The first-order interaction effect, Group x Tests, was not significant, $F(3, 54) = 0.53$, $p = .67$.

Table 2
ANOVA Summary Table for Systolic Blood Pressure

Source	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>p</u>
Between Subjects					
Group (G)	460.80	1	460.80	0.56	.46
Error	14768.40	18	820.47		
Within Subjects					
Tests (T)	218.40	3	72.80	4.22	.01
G x T	27.20	3	9.07	0.53	.67
Error	932.40	54	17.27		

Diastolic Blood Pressure

Diastolic blood pressure was measured before treatment and 30, 60, and 90 min after treatment. An ANOVA summary for diastolic blood pressure is given in Table 3. No significant difference was found between the diastolic blood pressures of the subjects in the high-caffeine-use group, $\bar{M} = 73.8$ mmHg, and the low-caffeine-use group, $\bar{M} = 72.9$, $F(1, 18) = 0.04$, $p = .85$. A significant difference was found among test time means, $F(3, 54) = 6.10$, $p = .00$. The means for the pretest, 30-min, 60-min, and 90-min tests were 70.9 mmHg, 75.2 mmHg, 74.7 mmHg, and 72.6 mmHg, respectively. The Tukey test, $HSD = 3.00$, $p < .05$, indicated the following significant differences between pairs of means: (a) the 30-min test mean was greater than the pretest mean and (b) the 60-min test mean was greater than the pretest mean. The first-order interaction effect, Group x Tests, was not significant, $F(3, 54) = 1.07$, $p = .37$.

Table 3
ANOVA Summary Table for Diastolic Blood Pressure

Source	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>p</u>
Between Subjects					
Group (G)	15.31	1	15.31	0.04	.85
Error	7131.13	18	396.17		
Within Subjects					
Tests (T)	231.33	3	77.11	6.10	.00
G x T	40.64	3	13.55	1.07	.37
Error	682.78	54	12.64		

Reaction Time

Reaction time was measured by a Visual Choice Reaction Time apparatus and was recorded before treatment as well as 30, 60, and 90 min after treatment. The ANOVA summary for reaction time is presented in Table 4. No difference was found between the reaction times of the subjects in the high-caffeine-use group, $\bar{M} = 0.45$ s, and the low caffeine use group, $\bar{M} = 0.44$ s, $F(1, 18) = 0.03$, $p = .85$. A significant difference was found among the test time means, $F(3, 54) = 9.00$, $p = .00$. The means for the pretest, 30-min, 60-min, and 90-min tests were 0.46 s, 0.45 s, 0.43 s, and 0.44 s, respectively. A significant first-order interaction effect, Group x Tests, was found, $F(3, 54) = 3.05$, $p = .04$. A simple main effect test showed a significant difference among the test times for the high-caffeine-use group, $F(3, 54) = 9.01$, $p < .05$. The Tukey test, $HSD = .026$, $p < .05$, indicated the following significant differences between pairs of means: (a) the pretest mean was greater than the 60-min test mean, and (b) the pretest mean was greater than the 90-min test mean.

Hand Steadiness

Hand steadiness was measured using a Groove Type Steadiness Tester and was recorded before treatment and 30, 60, and 90 min after treatment. The ANOVA summary for hand steadiness is presented in Table 5. No difference was found between the steadiness scores of the subjects in the high-caffeine-use group, $\bar{M} = 20.91$ cm, and the low-caffeine-use group, $\bar{M} = 20.27$ cm, $F(1, 18) = 1.42$, $p = .25$. No significant difference was found among test time means, $F(3, 54) = 0.33$, $p = .80$. The means of the pretest, 30-min, 60-min, and 90-min tests were 20.74 cm, 20.45 cm, 20.63 cm, and 20.54 cm, respectively. The first-order interaction effect, Group x Tests was not significant, $F(3, 54) = 0.36$, $p = .78$.

Table 4
ANOVA Summary Table for Reaction Time

Source	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>p</u>
Between Subjects					
Group (G)	0.00093	1	0.00093	0.03	.85
Error	0.50142	18	0.02786		
Within Subjects					
Tests (T)	0.01233	3	0.00411	9.00	.00
G x T	0.00418	3	0.00139	3.05	.04
Error	0.02466	54	0.00046		
Between Subjects					
Group at Pretest	0.00290	1	0.00290	2.74	
Group at 30 min	0.00056	1	0.00056	0.53	
Group at 60 min	0.00037	1	0.00037	0.35	
Group at 90 min	0.00128	1	0.00128	1.21	
Within Cell	0.07608	72	0.00106		
Within Subjects					
Time at High	0.01244	3	0.00415	9.01*	
Time at Low	0.00407	3	0.00136	2.95	
Within Cell	0.02466	54	0.00046		

* $p < .05$.

Discussion

The purpose of this study was to analyze the effect of caffeine on four

Table 5
ANOVA Summary Table for Hand Steadiness

Source	<u>SS</u>	<u>df</u>	<u>MS</u>	<u>F</u>	<u>p</u>
Between Subjects					
Group (G)	8.26	1	8.26	1.42	0.25
Error	104.84	18	5.82		
Within Subjects					
Tests (T)	0.90	3	0.30	0.33	0.80
G x T	0.97	3	0.32	0.36	0.78
Error	48.50	54	0.90		

dependent variables. Many significant differences were found among test time means for three out of four dependent variables. No significant differences were found between the means of the high-caffeine-use and low-caffeine-use groups for any of the dependent variables. This could be because the high caffeine use group abstained from caffeine before the study and may have been in the early stages of withdrawal; it could also be due to the high-caffeine-use group's expectancy of caffeine's stimulating effect. Braun (1996) stated that some parts of the brain may not become tolerant to caffeine; this may have contributed to the similarity in results between the high-use and low-use groups.

Significant differences were found among test time means for heart rate. The pretest, 30-min test, and 60-min tests were greater than the 90-min test. The 30-min and 60-min tests were expected to show higher heart rates because caffeine peaks in the blood between 30 and 60 min, and caffeine causes heart rate to rise (Kleiner, 1995). The pretest was not expected to show higher heart rates than the 90-min test, but results

showed rates in the pretest were significantly greater for both groups. This may have been due to test anxiety; subjects may have been nervous at the start of the test, resulting in accelerated heart rates. This would cause heart rate data to be abnormally high for the pretest. The lowering of heart rate in the 90 min test confirms that caffeine's effect tapered off after 60 min; the investigator believed if subjects had not been anxious about being tested and drinking 24 oz of coffee in 5 min, pretest heart rates would not have differed from 90 min heart rates. No significant difference was found between heart rate means for the high caffeine use group and low caffeine use group. This finding disagrees with findings of Eichner (1986), who stated that once tolerance to caffeine is developed, caffeine has little or no effect on heart rate.

The 60-min test mean was significantly greater than the pretest mean for systolic blood pressure. This was expected because caffeine raises systolic blood pressure (Eichner, 1986). The 60-min test was expected to show greater systolic pressures than the 90-min test. The 30-min test was also expected to show greater systolic pressures than the pretest and the 90-min test because caffeine can peak in the blood as early as 30 min. The fact that no significant differences were found among these tests disagrees with literature pertaining to caffeine's effect on systolic blood pressure. The lack of systolic pressure increase at the 30-min test time may have been due to caffeine peaking in the blood between 30 and 60 min.

There was no significant difference between systolic blood pressure means of the high-caffeine-use group and the low-caffeine-use group. Although Eichner (1986) stated that chronic coffee use results in little or no effect on blood pressure from caffeine, the lack of differences between the high and low use groups is in agreement with a study by Lotshaw et al. (1996), who found that tolerance to caffeine's blood pressure raising effect was not found in regular caffeine consumers. This could mean

people who regularly consume caffeine could experience a constantly elevated blood pressure throughout the day (Lotshaw et al., 1996).

Diastolic blood pressure was significantly greater in the 30-min and 60-min tests than in the pretest and 90-min test. This was expected because caffeine consumption causes increased blood pressure (Lotshaw et al, 1996). There was no difference between the diastolic pressure means of the high caffeine use group and the low caffeine use group. This also agreed with the results of Lotshaw et al. Diastolic pressures in the Lotshaw et al. study rose with caffeine use in chronic caffeine consumers.

There was no significant difference between reaction time means of the high-use and low-use groups. The low-caffeine-use group was expected to have a quicker reaction time response after caffeine ingestion, but the reaction time means between groups were only 0.01 s apart. This could be due to the expectancy of the high-use-group that caffeine would make them feel more alert. Once they ingested caffeine, they expected to feel more awake, resulting in faster reaction time scores.

There was a significant difference among test time means for reaction time, but a significant first-order interaction effect also existed. A simple main effect test showed that the significant difference occurred in the high-caffeine-use group; the pretest was greater than the 60-min and 90-min tests. The higher pretest score means reaction time was slower in the pretest. This result was not expected for the high-caffeine-use group but was expected for the low-caffeine-use group. A greater response was expected from the low caffeine use group, because caffeine decreases the time of motor reaction to visual stimuli, and chronic caffeine users are less affected by caffeine consumption (Eichner, 1986). Again, expectancy may be the reason the high caffeine use group showed a significant difference among test time means.

There was no significant difference between groups or among test time means for hand steadiness. A decrease in steadiness was expected because caffeine can impair fine motor coordination (Eichner, 1986). Caffeine users develop a tolerance to many of coffee's physiological effects (Eichner, 1986); this may explain why the high-caffeine-use group showed no significant difference among test time means. The lack of response from the low caffeine use group disputes the idea that caffeine may impair fine motor coordination (Eichner, 1996).

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study investigated the effects of caffeine on heart rate, blood pressure, reaction time, and hand steadiness. Males and females ($N = 20$), ages 18 to 30 years, served as subjects for this study. The subjects were volunteers meeting the following criteria: (a) not diagnosed as hypertensive or with cardiovascular disease, (b) not on a caffeine-restricted diet, and (c) not pregnant.

Subjects were classified into one of two groups based on self-reported caffeine intake. The first 10 volunteers who reported caffeine intake as greater than 1000 mg of caffeine per week were classified as high-caffeine users. The first 10 volunteers who indicated they consumed less than 200 mg per week were classified as low-caffeine users.

All four dependent variables (heart rate, blood pressure, reaction time, and hand steadiness) were measured before treatment and 30, 60, and 90 min after treatment. Heart rate was measured by a Polar heart rate monitor; a value was obtained in beats per minute by taking the average rate over 30 s. Reaction time was measured using a Visual Choice Reaction Time apparatus, made by the Lafayette Instrument Co., Lafayette, IN. Subjects were given visual stimuli in the form of a white light and were asked to depress a button in response to the light. Total reaction time was measured to the nearest thousandth second. Subjects performed 5 trials for reaction time; the highest and lowest scores were discarded, and an average of the remaining 3 scores was used as the score for reaction time. Hand steadiness was measured using a Groove Type

Steadiness Tester made by the Lafayette Instrument Co. Subjects slid a stylus along a mirrored track with raised sides; the left side of the track contained a ruler marked in centimeters. Subjects slid the stylus until they made contact with one of the raised sides. Five trials were performed, and the distance traveled with the stylus was recorded. The highest and lowest scores were discarded, and an average of the remaining 3 scores served as the subjects score for steadiness.

Findings

Significance for all findings of this study was determined at the .05 level. The ANOVA calculations indicated the following:

1. A significant difference was found among test time means for heart rate, $F(3, 54) = 8.31, p = .00$. The pretest, 30-min test, and 60-min test means were all greater than the 90-min test mean.
2. A significant difference was found among test time means for systolic blood pressure, $F(3, 54) = 4.22, p = .01$. The 60-min test mean was greater than the pretest mean.
3. A significant difference was found among test time means for diastolic blood pressure, $F(3, 54) = 6.10, p = .00$. The 30-min and 60-min test means were greater than the pretest mean.
4. A significant difference was found among test time means for reaction time, $F(3, 54) = 9.00, p = .00$.
5. A significant first-order interaction effect, Group x Tests, was found among test time means for reaction time, $F(3, 54) = 3.05, p = .04$
6. A significant difference was found among test time means in the high caffeine use group for reaction time, $F(3, 54) = 9.01, p < .05$. The pretest mean was greater than the 60-min and 90-min test means.

7. No difference was found between the high-use and low-use groups for heart rate, systolic blood pressure, diastolic blood pressure, or hand steadiness.

Conclusions

The following conclusions were made as a result of this study:

1. Caffeine did not increase heart rate significantly for either group.
2. Caffeine increased systolic blood pressure 60 min after caffeine intake for both the high caffeine use group and the low caffeine use group.
3. Caffeine increased diastolic blood pressure at 30 and 60 min after caffeine intake for both the high caffeine use group and the low caffeine use group.
4. Caffeine decreased reaction time for the high caffeine use group at 60 and 90 min.
5. Caffeine had no effect on hand steadiness for either group.

Recommendations

Based on this investigation's research design and findings, the following recommendations for further study are suggested:

1. Use a balanced placebo design to see if regular caffeine users respond because of caffeine or as a result of expectancy.
2. Add respiration rate and temperature as dependent variables to the design of the study.
3. Add a group of regular smokers to see if the combination of caffeine and nicotine causes a more significant physiological reaction.
4. Design the study to measure baseline heart rate and blood pressure prior to administering the caffeine treatment.

Appendix A
Screening Form

SUBJECT SCREENING FORM

Please circle yes or no to the following questions.

Yes No 1. Have you ever been diagnosed with a heart problem?

Yes No 2. Have you ever been diagnosed with high blood pressure?

Yes No 3. Has a physician ever told you to restrict caffeine?

Yes No 4. Are you pregnant?

Appendix B
Consent Form

Western Michigan University

Department of Health, Physical Education, and Recreation

Principal Investigator: Dr. Mary Dawson

Student Investigator: Amy K. Ryan

I have been invited to participate in a research project entitled "The Effect of Caffeine on Reaction Time, Hand Steadiness, and Specific Physiological Variables". I understand that this research is intended to study how caffeine affects reaction time, hand steadiness, heart rate, and blood pressure. I further understand that this project is Amy Ryan's master's thesis project in the Department on Health, Physical Education, and Recreation at Western Michigan University.

My consent to participate in this project indicates that I will be asked to attend one two hour private session with Amy Ryan. I will be asked to meet her in the Exercise Physiology Lab, room 1061 of the Student Recreation Center at Western Michigan University. The session will involve drinking a 24 oz cup of coffee. The 24 oz cup of coffee will be consumed in 5 minutes. Reaction time, hand steadiness, blood pressure, and heart rate will be recorded.

As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken; however, no compensation or treatment will be made available to me except as otherwise specified in this consent form. I understand one potential risk is mild discomfort if I am not used to consuming caffeine. I understand, however, that I can terminate my involvement with this research for any reason at any time without prejudice or without affecting my academic evaluation in any way.

I may benefit from my participation by learning more about the effect caffeine has on my body. I also understand others who include caffeine in their diet can learn new information from this study. I may also better understand how reaction time and hand steadiness can be measured and how they are specifically affected by three cups of coffee.

I understand all information collected from me is confidential. My name will only appear on this form and on a list of identification codes, and no individual names will be printed on any papers or reports other than this form, which will only be seen by the investigators. After data collection is complete, the list of codes will be destroyed. All data will be retained for a period of 3 years in a locked file in the principal investigator's office. At the conclusion of the study, I will be able to receive a copy of my results upon request.

If I have any questions or concerns about this study I may contact Amy Ryan at 387-3543 or Dr. Mary Dawson at 387-2720. I may also contact the chair of Human Subjects Institutional Review Board at 387-8293 or the Vice President for research at 387-8298. My signature below indicates that I understand the purpose and requirements of the study and that I agree to participate.

Signature

Date

Appendix C

Human Subjects Institutional Review Board Acceptance Letter



WESTERN MICHIGAN UNIVERSITY

Date: 29 October 1997

To: Mary Dawson, Principal Investigator
Amy Ryan, Student Investigator

From: Richard Wright, Chair

A handwritten signature in cursive script that reads "Richard A. Wright".

Re: HSIRB Project Number 97-10-02

This letter will serve as confirmation that your research project entitled "The Effect of Caffeine on Reaction Time, Hand Steadiness, and Specific Physiological Variables" has been approved under the **expedited** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: 29 October 1998

Appendix D
Data Collection Sheet

Data Collection Sheet

Subject _____

Pretest

HR _____
BP _____

Reaction Time

Trial 1 _____
Trial 2 _____
Trial 3 _____
Trial 4 _____
Trial 5 _____

Hand Steadiness

Trial 1 _____
Trial 2 _____
Trial 3 _____
Trial 4 _____
Trial 5 _____

30 min posttest

HR _____
BP _____

Reaction Time

Trial 1 _____
Trial 2 _____
Trial 3 _____
Trial 4 _____
Trial 5 _____

Hand Steadiness

Trial 1 _____
Trial 2 _____
Trial 3 _____
Trial 4 _____
Trial 5 _____

60 min posttest

HR _____
BP _____

Reaction Time

Trial 1 _____
Trial 2 _____
Trial 3 _____
Trial 4 _____
Trial 5 _____

Hand Steadiness

Trial 1 _____
Trial 2 _____
Trial 3 _____
Trial 4 _____

Trial 5 _____

90 min posttest

HR _____
BP _____

Reaction Time

Trial 1 _____

Trial 2 _____

Trial 3 _____

Trial 4 _____

Trial 5 _____

Hand Steadiness

Trial 1 _____

Trial 2 _____

Trial 3 _____

Trial 4 _____

Trial 5 _____

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