THE PHYSIOLOGICAL EFFECTS OF CAFFEINE DURING AEROBIC DANCE BENCH STEPPING AND TREADMILL WALKING

THESIS

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CHAPTER 1

INTRODUCTION

Caffeine is commonly used as an ergogenic aid to improve performance in many types of athletic endeavors (20, 37). While the benefits of caffeine on aerobic athletic performance, including cross-country skiing (6), cycling (31), rowing (1), and running (49), the cardiovascular and metabolic effects of caffeine during treadmill walking (15), treadmill running (49), stationary rowing (25), and stationary cycling (5) in men of different training levels and in trained women are unclear. Furthermore, a Medline search revealed no studies investigating the effect of caffeine on physiological responses to common modes of recreational physical activity, such as group exercise and walking, in untrained females of average fitness levels.

Some studies have shown that caffeine intake prior to exercise increases oxygen cost (16, 36). For example, Fisher et al. (16) reported that ingestion of caffeine (5 mg kg^{-1}) prior to running on a treadmill for 6 minutes at 75% VO_2max resulted in a significantly higher VO_2 (0.17 L min^{-1}) among 6 women habituated to caffeine. However, other studies found that caffeine had no effect on oxygen cost of exercise (7, 8, 19, 45). Birnbaum et al. (7) concluded that ingestion of caffeine (7 mg kg^{-1}) prior to running on a treadmill for 30 minutes at 70% VO_2max did not affect average steady-state VO_2 among 10 male and female cross country runners, 9 of which were not habituated to caffeine. Similarly, Engels et al. (15) investigated the effects of caffeine ingestion (5 mg kg^{-1}) on treadmill walking at lower intensities (30% VO_2max and 50% VO_2max) in 8 sedentary males, who were not habituated to caffeine, and found no effect on VO_2 and respiratory exchange ratio (RER). As a result of caffeine consumption before exercise, if oxygen cost increases, then energy expenditure also increases. Such an effect would be of significance to a recreational exercise, esp. one who is interest in losing weight.

Studies have shown that caffeine may increase heart rate (5, 27), decrease (7), and have no effect on HR (36, 42) during exercise of highly trained athletes. The discordance in the literature may be due to the different doses used, ranging from 3 to 9 mg kg^{-1} (11, 13, 16, 30, 33, 38, 45, 46), and/or the subjects' habitual consumption of caffeine (5). When habituation to caffeine consumption is considered, caffeine ingestion prior to exercise appears to have a greater impact on HR in users than nonusers during exercise (5, 27). For example, Bell et al. (5), measured HR of both users and nonusers of caffeine during 5 minutes of cycling at 50% VO_2max followed by cycling to exhaustion at 80% VO_2max at 1, 3, and 6 hours post-consumption. When compared to caffeine users, the magnitude of the increase in HR following ingestion of caffeine was greater in the nonusers (5).

Previous research has consistently reported that caffeine consumption reduces RPE in highly trained users and nonusers of caffeine during cycling at a dosage amount of 5 mg kg^{-1} (5, 13), running at a dosage of 7 mg kg^{-1} (7, 19), and rowing at a dosage of 6 mg kg^{-1} and 9 mg kg^{-1} (1). However, no study has addressed whether caffeine reduces RPE during common forms of aerobic activity, such as aerobic dance bench stepping (ADBS) and treadmill walking. As a result of caffeine consumption prior to exercise, a decrease in RPE may make the recreational exerciser feel that exercise is easier and may enable him/her to exercise longer.

The American College of Sports Medicine (2) recommends exercising 3-5 days per week at 50% to 80% of oxygen uptake reserve (VO_2R)(2). Aerobic dance bench stepping (ADBS) and walking are popular ways to incorporate exercise into individual's daily routines while meeting the guideline set for achieving an active lifestyle (39). Because caffeine consumption among adults is on the rise (17), the combination of exercising while under the influence of caffeine is probable. During ABDS, common procedures to monitor intensity include measuring RPE and HR. Accurate measures of HR and RPE are critical for optimal exercise prescription.

To date, most of the studies on caffeine have focused on its performance enhancing effects. A possible interest to recreational exercisers and health and fitness professionals may be caffeine's effects on caloric expenditure during common modes of aerobic exercise and on the ability to monitor exercise using heart rate (HR) and rate of perceived exertion (RPE). The purposes of this study were to determine: 1) the effects of two different doses of caffeine on HR, RPE, and VO_2 during choreographed aerobic dance bench stepping (ADBS), and 2) whether the effects of caffeine if any, vary between users and non-users of caffeine. The results of this study may be used to determine whether caffeine affects the ability caffeine users' and non-users' to accurately monitor exercise intensity during ADBS using HR and RPE. Based on previous research concerning the effects of caffeine on HR and RPE (7, 13, 19, 27, 36, 42), we hypothesized that moderate doses of caffeine (6 mg kg^{-1}) when compared to lower doses of caffeine (3 mg kg^{-1}) ingested 45 minutes prior to ADBS at a given workload will: 1) elevate HR, 2) decrease RPE, and 3) have no effect on oxygen consumption (VO_2).

CHAPTER 2

METHODS

Experimental Approach to the Problem

The effects of an acute dose of caffeine on the cardiovascular and metabolic responses to common modes of aerobic exercise in women of average fitness levels have not been reported in the literature. Based on intervals of 3 mg of the commonly tested dose range of 3 – 9 mg kg^{-1} (20), the initial purpose of this study was to determine the effects of three different caffeine trials (3, 6, and 9 mg kg^{-1}) on the cardiovascular and metabolic responses to ADBS and treadmill walking (94 m min^{-1}). During the first trial, 7 of the 10 females, who received a 9 mg kg^{-1} caffeine dose (527 - 871 mg), experienced adverse reactions (e.g., profuse sweating, body tremors, dizziness, and vomiting). Therefore, the remaining 9 mg kg^{-1} caffeine trials were eliminated from the study protocol, and the results from the 20 subjects that completed the placebo trial, the low dose trial (3 mg kg^{-1}), and the medium dose trial (6 mg kg^{-1}) were used in final data analyses. Accordingly, this study determined whether differences in metabolic and cardiovascular responses for treadmill walking and ADBS existed between: 1) 3 mg kg^{-1} of caffeine and the placebo, 2) 6 mg kg^{-1} of caffeine and the placebo, and 3) 3 and 6 mg kg^{-1} of caffeine.

The order of treatment was randomly assigned for each subject. Heart rate (HR), oxygen consumption (VO_2), rate of energy expenditure (REE) in kcal min^{-1}, respiratory exchange ratio (RER), and rate of perceived exertion (RPE) were recorded for each minute during the 8-minute tests. Mean values calculated from the final three minutes of each test were used for data analysis. An analysis of variance (ANOVA) with repeated measures was used to determine the effect of varying doses of caffeine (3 and 6 mg kg^{-1}) on the averages of VO_2, HR, REE, RER, and RPE for the final 3 minutes of each test. Post-hoc paired t-tests were conducted to determine whether differences in mean VO_2, HR, REE, RER, and RPE for walking and ADBS exist between: 1) 3 mg kg^{-1} of caffeine and the placebo, 2) 6 mg kg^{-1} of caffeine and the placebo, and 3) 3 and 6 mg kg^{-1} of caffeine.

Subjects

Subjects (n=20) included female volunteers from an aerobics course at Texas State University. These subjects were between the ages 19-28. To ensure that the subjects could follow a video taped ABDS routine and reduce the risk of injury, subjects will go through at least 2 introductory classes to ABDS. A written consent document will be obtained from each participant after a detailed description of the procedures is provided.

Of the 26 original volunteers, 3 females withdrew due to personal problems and 3 females withdrew due to adverse reactions to the high caffeine dose (9 $mg \cdot kg^{-1}$). Also, during the first trial, 7 of the 10 females, who received a 9 $mg\,kg^{-1}$ caffeine dose (264 - 749 mg), experienced adverse reactions (e.g., profuse sweating, body tremors, dizziness, and vomiting). As a result, only 5 of these subjects completed the remaining trials. The results from the 20 subjects that completed a placebo trial, a low dose trial (3 $mg\,kg^{-1}$), and a medium dose trial (6 $mg\,kg^{-1}$) were used in final data analyses. Of the 20 women who completed testing the highest VO_2 max was 46.0 and the lowest was 22.9, all of which are considered average fitness by the American College of Sports Medicine (ACSM). This sample appears to represent female college aged students who are of average fitness levels.

Table 1 reports the subject's descriptive characteristics. The sample of college females appears to be representative of active and moderately fit women. The sample excludes unfit and inactive females.

Table 1. Descriptive Statistics

Variables	Mean ± SD	Range
Age	22.4± 2.2	19.0-28.0
Height (cm)	165.1±7.7	152.4-177.8
Weight (kg)	72.6±10.6	58.6-96.8
Peak VO_2(ml kg^{-1} min^{-1})	31.9±6.0	22.9-46.0

Testing Procedures

Each subject visited the laboratory on four different occasions 2 to 7 days apart. Interested participants were instructed to sign up for an initial visit to the lab. They will be given pre-test instructions instructing them, prior to each lab visit as per American College of Sports Medicine guidelines, to: 1) abstain from food and beverages for 1 to 2 hours, 2) abstain from tobacco products for 3 hours, 3) drink plenty of fluids in the 24 hours prior, 4) get the recommended 6-8 hours of sleep on the night prior to each testing day, 5) Refrain from strenuous exercise 24 hours prior to testing, 6) wear comfortable clothes and exercise appropriate shoes on testing day, and 7) abstain from alcohol and caffeine for 12 hours.

During visit #1, subjects : 1) signed informed consent, 2) completed health appraisal, 3) completed caffeine intake questionnaires, 4) were measured for height and weight (Detecto Scale Co., Jerico, New York), 5) were tested for VO_2 max using the Bruce protocol on a trackmaster treadmill (Fullvision, Newton, KS)to ensure average fitness level, and 6) were given pre-test instructions. After height and weight, caffeine (Spectrum Chemicals, New Brunswick, NJ) was prepared and placed into coded envelopes by a person who was not involved in data analysis. The envelopes were identified by the subject's name and date they were to take the given capsules. Placebo capsules were filled with dextrose (Spectrum Chemicals, New Brunswick, NJ) which had the same color and texture as the caffeine. During visit #2, subjects were randomly administered in a double blind method, 3 mg kg^{-1}, 6 mg kg^{-1}, or 9 mg kg^{-1} of caffeine, or a placebo with an 8 oz. serving of water. Subjects were asked to show up 45 minutes before the appointment time on trials 2, 3, and 4 to ingest the capsules. After 45 minutes following the consumption of caffeine, subjects were fitted with a heart rate monitor (Polar Vantage XL telemetric, Stanford, CT) and mouthpiece connected to a metabolic analyzer (PARVO medics metabolic analyzer Salt Lake City, UT) and, then, asked to follow an 8-minute video-taped aerobic dance bench stepping routine. Following the ABDS video, subjects rested for 10 minutes and then instructed to walk on the treadmill for 8 minutes at 3.5 mph. For the third and fourth visits to the lab, subjects were given either a dose of caffeine or a placebo, and instructed to rest for 45 minutes. After the rest period, subjects were again instructed to follow the same videotaped ABDS routine followed by the treadmill walking.

Subjects were required to keep a three consecutive day food journal and to repeat the food eaten for the 24- hour period prior to trial 2, for the 24-hour period preceding trials three and four. During the 24-hour period before trial two, subjects were asked to eat in the manner that they would eat prior to a regular workout. This information was analyzed for various behaviors that could skew results.

Statistical Analysis

An analysis of variance (ANOVA) with repeated measures were conducted to determine the effect of varying doses of caffeine (3, and 6 mg kg^{-1}) on the averages of VO_2, HR, and RPE for the final 3 minutes of each test. Post-hoc paired t-tests were conducted to determine whether differences in mean VO_2, HR, and RPE exist for ABDS and treadmill walking between: 1) 3 mg kg^{-1} of caffeine and the placebo, 2) 6 mg kg^{-1} of caffeine and the placebo, and 3) 3 and 6 mg kg^{-1} of caffeine.

CHAPTER 3

RESULTS

After analyzing the nutritional data provided by the subjects, it was determined that all subjects were considered non-habitual users (< 300 mg of caffeine daily) of caffeine. Bell and McLellan (5) considered caffeine "users" to be individuals whose daily caffeine consumption exceeds 300 mg. The range of daily caffeine consumption was 0 - 76 mg daily.

Tables 2 and 3 report the physiological and metabolic data (mean and SD) collected from the sample. RPE, HR, VO2, RER, and REE values are reported for each of the three different doses of caffeine.

Table 2. Metabolic responses of caffeine and ABDS

Variable	Control	3 mg	6 mg
RPE	10.36±2.3	10.26±2.5	9.85±2.4
HR (beats min^{-1})	170.3±16	170.7±16.8	171.68±17.5
VO_2(ml kg^{-1} min^{-1})	24.99±3.4	25.8±3.1	26.4±2.8
RER	.99±.06	.99±.07	1.0±.07
REE (kcal min^{-1})	9.1±1.4	9.4±1.4	9.5±1.3

Note: RPE= Rate of Perceived Exertion, HR = Heart Rate, VO_2= Oxygen Consumption, RER = Respiratory Exchange Ratio, REE = Energy Expenditure

Table 2 reports the subjects' responses during the aerobic dance bench stepping portion of the experiment. A repeated measures ANOVA revealed that there were no significant differences among the different dosage amounts (control, 3 mg kg^{-1} dose of caffeine, 9 mg kg^{-1} of caffeine) for any of the metabolic responses: 1) RPE ($F= .594$, $p > .05$) 2) Heart rate ($F= .761$, $p > .05$) 3) Absolute VO_2 ($F = 2.66$, $p > .05$) 4) RER ($F = .834$, $p > .05$) 5) REE ($F = 3.0$, $p > .05$)

Table 3. Metabolic Responses to caffeine and treadmill walking (3.5 mph)

Variable	Control	3 mg	6 mg
RPE	8.7±2.8	8.7 ±2.5	8.1±2.2
HR(beats min^{-1})	139.3±18.5	140.4 ±18.6	138.3±18.7
VO_2(ml kg^{-1} min^{-1})	16.2 ±1.8	16.8±1.7	16.9±1.8
RER	.88±.05	.86±.04	.86±.06
REE(kcal min^{-1})	5.8 ±1.1	6.0 ±1.2	6.0 ±1.2

Note: RPE= Rate of Perceived Exertion, HR = Heart Rate, VO_2= Oxygen Consumption, RER =Respiratory Exchange Ratio, REE = Energy Expenditure

Table 3 reports the subjects metabolic responses (means and SD) while walking on a treadmill at 3.5 mph. A repeated measures ANOVA revealed significant differences ($p < .05$) among doses of caffeine in: 1) VO_2 ($F= 3.56$, $p < .05$) and 2) REE ($F = 4.0$, $p < .05$). Post-Hoc tests showed a significant difference in 6 mg kg^{-1} dose (16.9±1.8) when compared to the placebo (16.3±1.8), but no difference between the 3 mg kg^{-1} dose

(16.8±1.7) and either the placebo or 6 mg kg^{-1}dose (t_{19} = .02, p>.05). However no significant differences (p > .05) between caffeine doses were observed for 1) RPE (F = 1.9, p = .17) 2) HR (F= .96, p= .39) and 3) RER (F= .77, p= .47).

Figure 1: Rate of Perceived Exertion and Aerobic Dance Bench Stepping

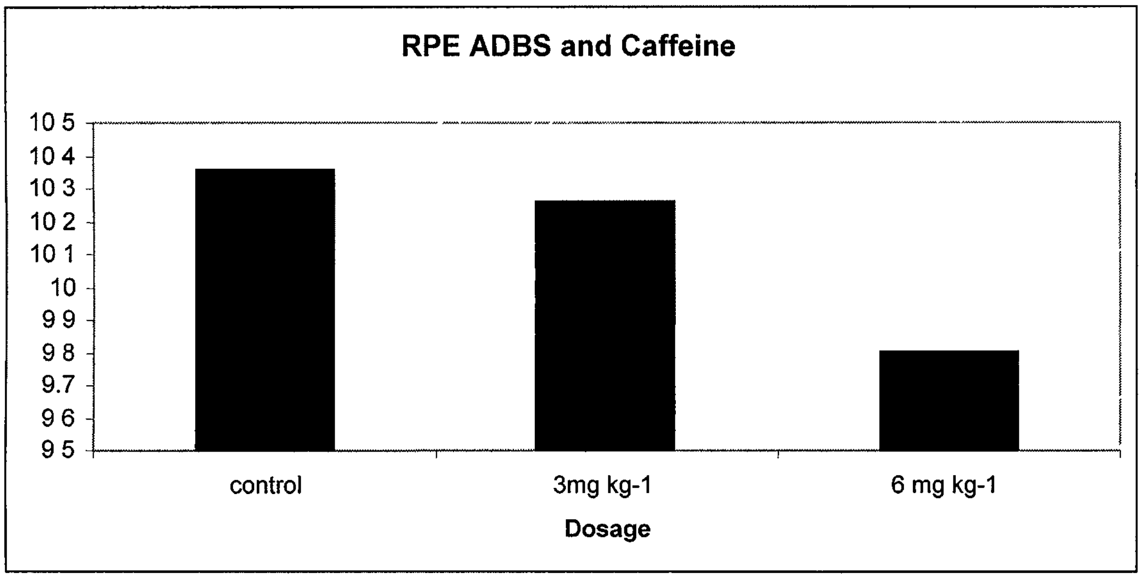


Figure 2: Heart Rate and Aerobic Dance Bench Stepping

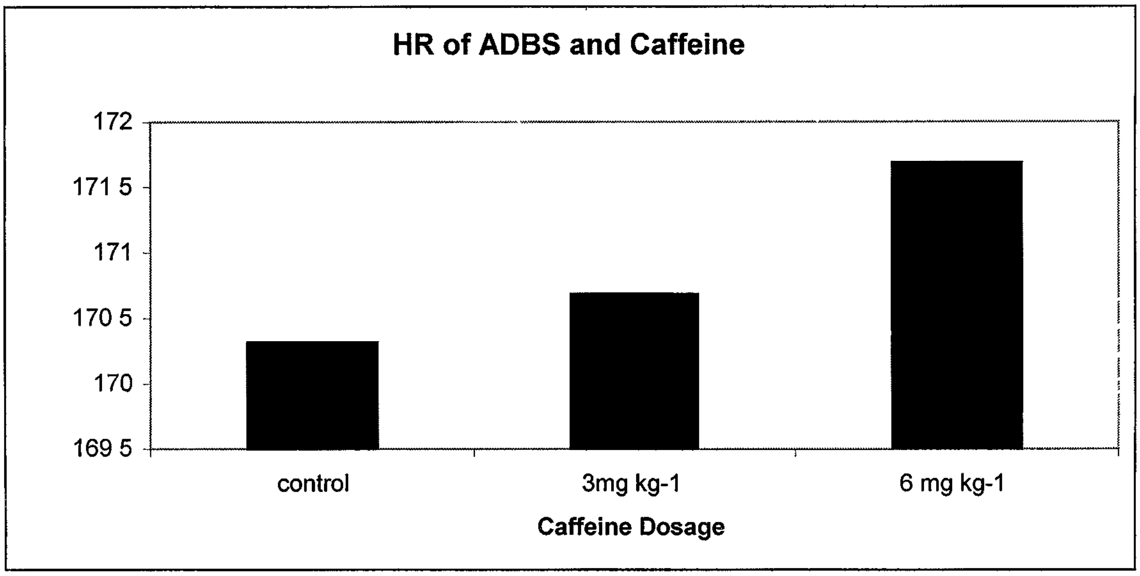


Figure 3: Oxygen Consumption and Aerobic Dance Bench Stepping

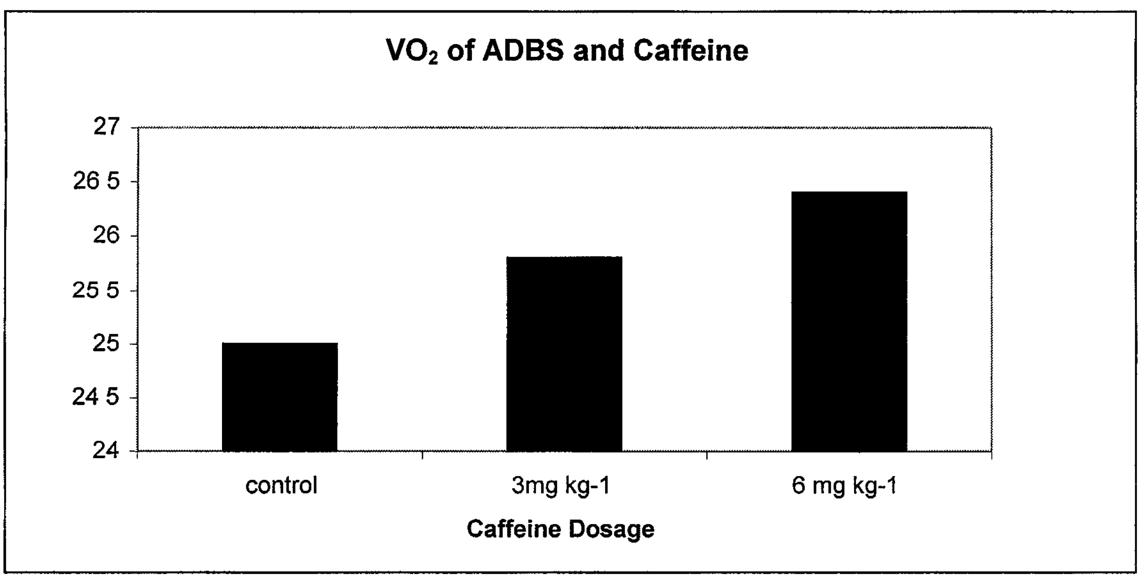


Figure 4: Respiratory Exchange Ratio and Aerobic Dance Bench Stepping

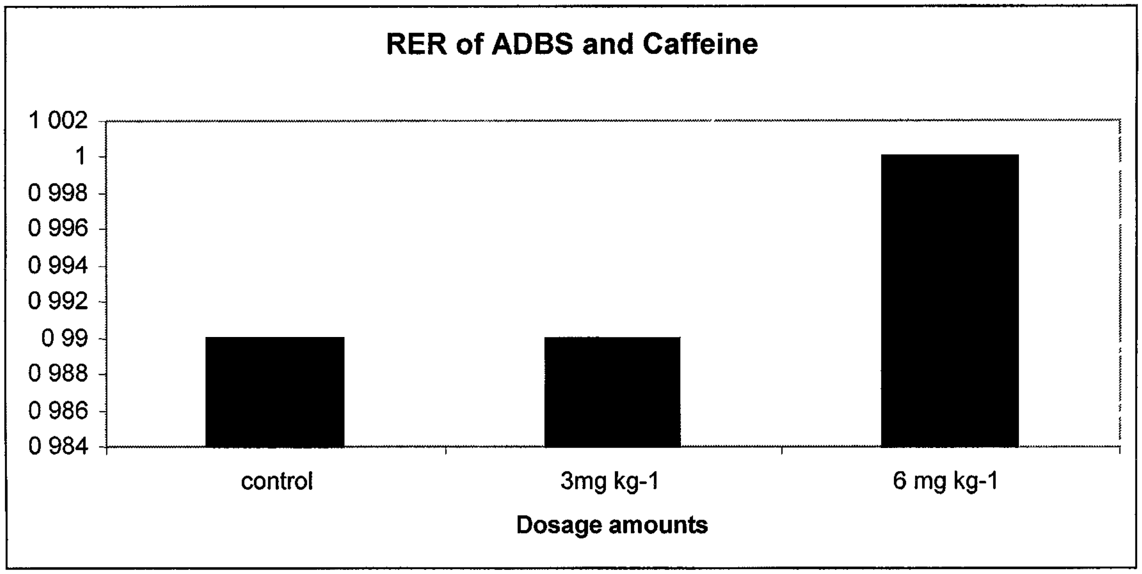


Figure 5: Caloric Expenditure and Aerobic Dance Bench Stepping

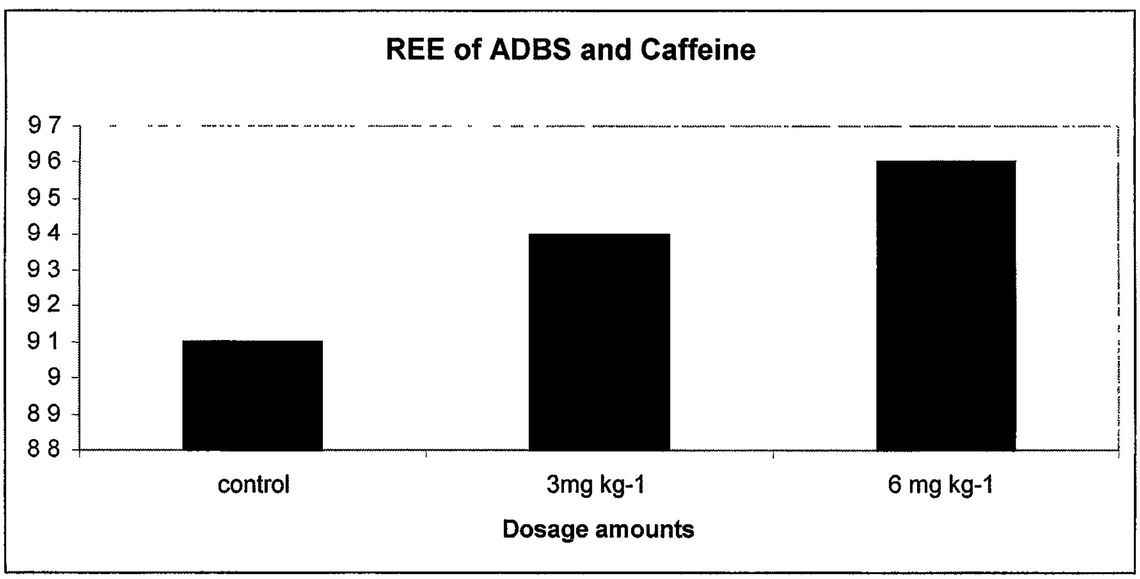


Figure 6: Rate of Perceived Exertion and Treadmill walking 3.5 mph

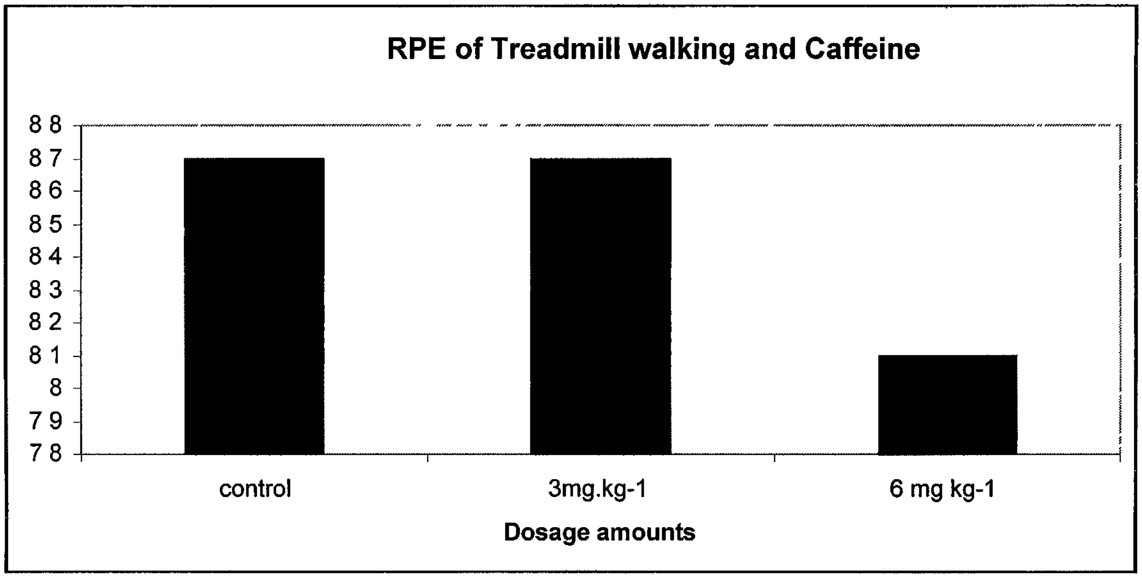


Figure 7: Heart Rate and Treadmill walking 3.5 mph

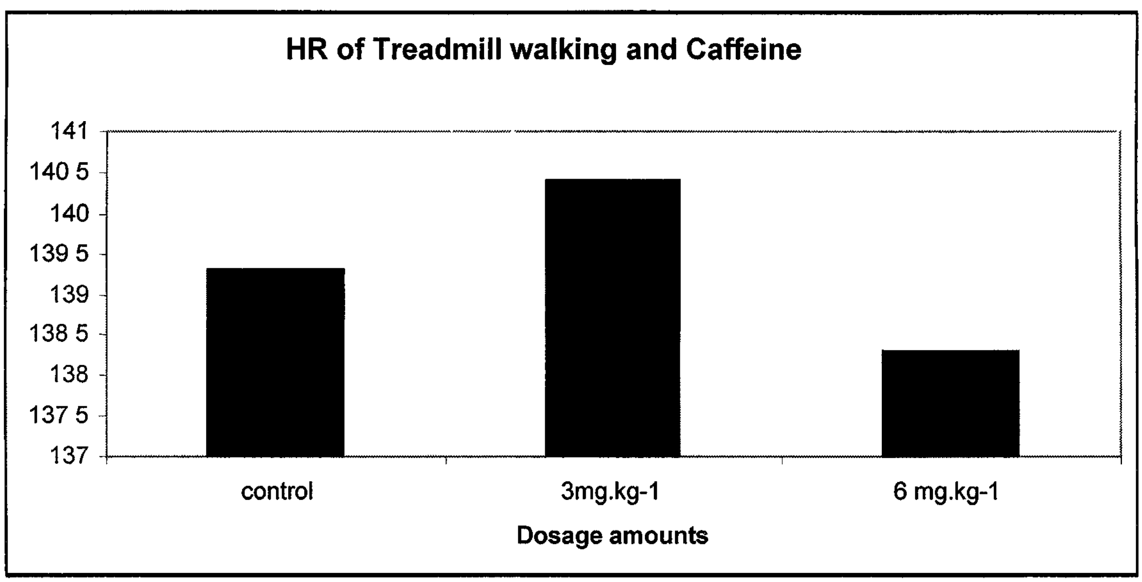
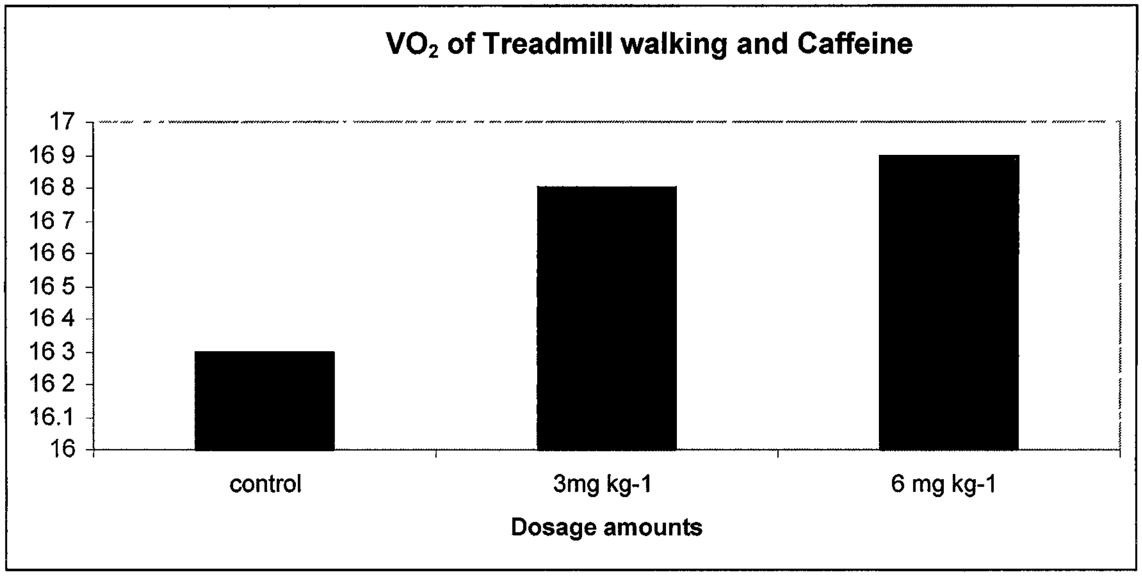


Figure 8: Oxygen Consumption and Treadmill walking 3.5 mph



* Significance found among sample

Figure 9: Respiratory Exchange Ratio and Treadmill walking 3.5 mph

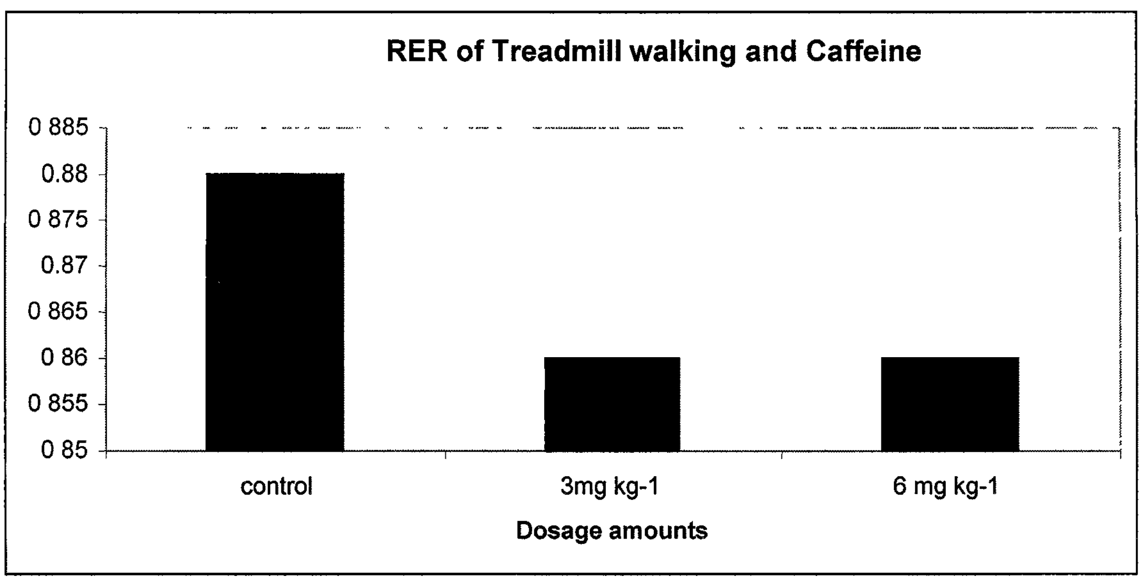
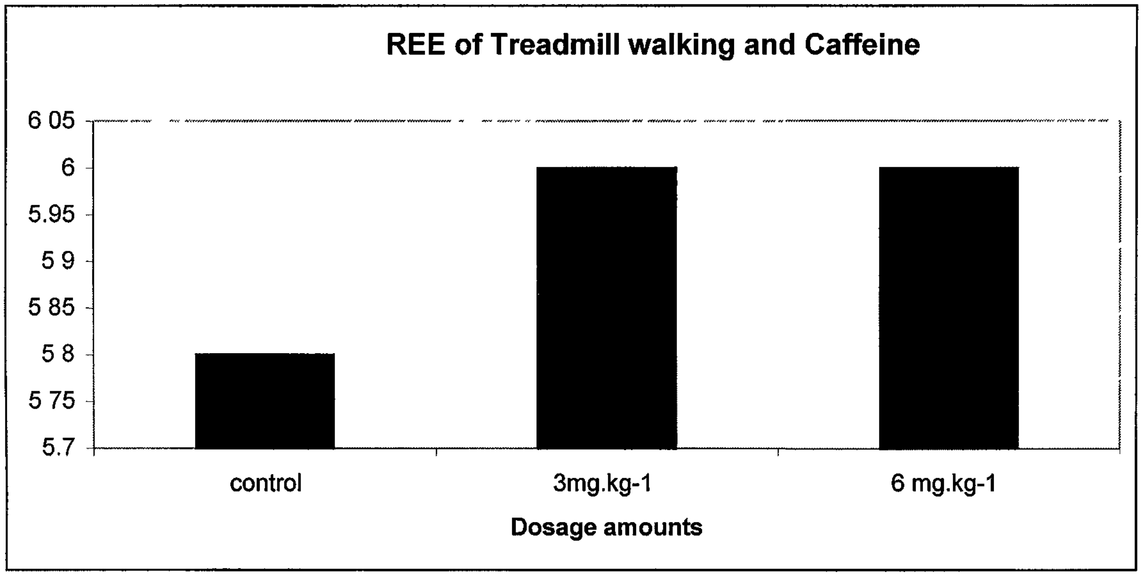


Figure 10: Caloric Expenditure and Treadmill walking 3.5 mph



* Significance found among sample

CHAPTER 4

DISCUSSION AND CONCLUSIONS

Previous research has demonstrated that under certain circumstances caffeine can ergogenically aid performance (1, 5, 7, 13, 27, 42). Whiles males and athletes have been studied extensively, there is no previous research examining the effects of caffeine on women of average fitness. This study examined the subjects': RPE, HR, VO_2, RER, and REE after ingesting a placebo, 3 mg kg^{-1}, and 6 mg kg^{-1} doses of caffeine. The results from this study indicate that caffeine does not alter RPE, HR, VO_2, RER, and REE during ADBS in women of average fitness. However, while walking on a treadmill at 3.5 mph, the large dose (6 mg kg^{-1}) of caffeine did cause an increased oxygen consumption along with an increase in REE.

The results of this study suggest that the metabolic responses HR, VO_2, REE, and RER as well as RPE during ADBS under the influence of either the small or large dose of caffeine were not statistically significant. This result is supported by previous investigations. Birnbaum et al. (7), also concluded that ingestion of caffeine (7 mg kg^{-1}) prior to running on a treadmill for 30 minutes at 70% VO_2max did not affect average steady state VO_2 among 10 college students, 9 of which were non- habitual users. Similarly, Engels et al. (15) investigated the effects of caffeine ingestion (5 $mg \cdot kg^{-1}$) on treadmill walking at lower intensities (30% VO_2max and 50% VO_2max) by 8 males reporting habitual caffeine consumption less than 300 mg day^{-1} and found no effect on oxygen consumption.

In contrast, the current study did find significant differences, during treadmill walking at 3.5 mph when observing the individuals under the influence of the 6 mg kg^{-1} dosage for VO_2 and REE. While statistically significant, this increase was only .7 (ml kg^{-1} min^{-1}). For the treadmill walking test, the large dosage of caffeine also caused an increase in REE from a mean of 5.8 kcal/min in the placebo trial to 6.0 kcal/min in the large dosage trial. Since VO_2 increased without a concomitant increase in HR following caffeine supplementation during moderate treadmill walking, caffeine may increase cardiovascular efficiency. Cardiovascular efficiency may be measured by oxygen pulse i.e VO_2/HR, a method commonly used in cardiac rehabilitation settings. The Fick equation i.e. $VO_2 = HR \times SV \times A - VO_2 \Delta$ may also be explanatory of why VO_2 increased without the linear expected increase in HR. Hartley et al. (23), reported that at rest after caffeine supplementation, the women showed a higher SV. The 3 remaining metabolic variables: RPE, HR, and RER showed no change during treadmill walking.

There is no previous research on the effects of caffeine and the metabolic responses of women of average fitness, therefore the caffeine doses originally chosen were those consistent with previous research on male subjects, intervals of three from 3-9 mg kg^{-1} (11, 13, 16, 29, 30, 33, 35, 38, 45, 46). As a result, this study began with a high dosage of 9 mg kg^{-1} similar to that reported in studies of male subjects (11, 13, 16, 29, 30, 33, 35, 38, 45, 46).During the pilot study, it became obvious that the women in this study were not able to tolerate this high dosage (9 mg kg^{-1}) of caffiene. Of the 10 women who ingested the 9 mg kg^{-1}dosage, 7 of them experienced adverse effects. These effects included: profuse sweating, body tremors, and vomiting. Consequently, McNaughton et al. (35), found that the lowest RPE rating came from the largest doses (9 mg kg^{-1}) in male participants.

Many previous studies test for VO_2 changes, yet many studies failed to find changes have also found that caffeine does not alter VO_2, minute ventilation (VE), blood pressure (BP), or heart rate (HR) during sub-maximal exercise (7, 8, 19, 45). For example, Tarnopolsky (45), tested male runners at 70% VO_2 m ax and found no statistically reliable changes in VO_2, HR, or RPE as a result of 6 mg kg^{-1} of caffeine. Bond et al. (8), found no significant changes in maximal VO_2, HR, or VE. Birnbaum et al. (7), also found that there were no significant changes in the cardio-respiratory responses following 7 mg $kg^{-1}$of caffeine, and the authors argued that it is unlikely that caffeine provides a higher energy expenditure during moderate exercise since VO_2, HR, and BP were unchanged.

Nishijima et al. (36) reported that at rest and exercise VO_2 and respiratory gas exchange ratio showed no significant difference between groups and trials. This could possibly be explained by a shift in macronutrient use to become more reliant on fat utilization. The differences in metabolic responses to caffeine across modes of exercise suggest that caffeine may only have an effect on moderate intensity exercise (50% VO_2 max).

There are several factors that can explain the contradictions in these results. For example, in the present study, the 45 minute post consumption time is consistent with previous research, and considered an appropriate time length for absorption (, 14, 29, 33, 37, 45). Jacobsen et al. (29), reported beginning testing 45 minutes post consumption to aid in caffeine absorption prior to the reaction time and movement time testing. Caffeine has a half-life 4-6 hours. This implies that large quantities would stay in the blood for 3-4 hours after ingestion; consequently most studies focus on up to 1 hour after consumption (5).

Habitual use of caffeine has been suggested as a potentially confounding source of variation in determining the ergogenic effect of caffeine (5). Bell and McLellan (5) considered caffeine "users" to be individuals whose daily caffeine consumption exceeds 300 mg per day. In the present study, all subjects consumed < 300 mg of caffeine on a daily basis. Subjects were instructed to abstain from caffeine usage 12 hours prior to testing, consistent with previous testing procedures (9, 13, 16, 27). Previous research has shown that abstinence between 6 and 24 hours was a sufficient amount of time for absorption of the caffeine (9, 13, 16, 27). The difference between habitual and non-habitual users appears to be most pronounced as a result of the duration of the exercise testing. Bell et al. (5) reported that the significant differences in the metabolic responses during time to exhaustion in trained cyclists, did not occur in nonusers of caffeine until minute 10 into the test (5). Perhaps significant differences in RPE, HR, and RER would have occurred if testing time was longer than the 8-minute bouts that were used in the current study.

Subjects were instructed to journal 3 consecutive days of eating and drinking as they would normally would. This method of nutritional documentation is consistent with that of Engels et al. (15). The authors insisted that subjects follow their normal eating patterns during data collection (15). The eating pattern recorded 24 hours prior to the first day of testing was photo copied and given back to the subjects. The subjects were then asked to follow that eating pattern as closely as possible. They were instructed to journal any discrepancies that may come about during the 24 hour period prior to testing days. This method proved to be successful as subjects were willing to follow the same menu.

The 3-day journals were entered into a nutrition database and analyzed looking for low or high carbohydrate, fat, and calorie intake. A nutritionist concluded that all subjects appeared to have a normal diet free from any unusual eating patterns. The subjects were also considered to be moderately active at the time of the study, since they subjects were enrolled in an aerobics class that met 4 days per week.

Practical Application

It can be concluded that (n = 20) college-aged women (19 - 28) who are non-habitual caffeine users (< 300 mg daily) and are moderately active do not show a decrease in RPE, HR, VO_2, RER, and REE due to caffeine consumption prior to aerobic dance bench stepping (ADBS). Although significant differences found in VO_2 and REE during treadmill walking (3.5 mph) were observed during the large dose trial, the other metabolic responses were left unchanged as a result of caffeine ingestion. Although the results of this study suggest that caffeine does not aid in exercise for women of average fitness, there are other factors to consider. For example, the time in which data was collected was perhaps too short to show the true nature of the effects of caffeine. This study supports the idea that caffeine will not hinder the abilities of women of average fitness while engaging in sub-maximal exercise. However, this study did show that during treadmill walking at 3.5 mph, VO_2 and REE were increased significantly from the placebo trials to the high dosage (6 mg kg^{-1}) trial. This study also showed that that female body is unable to break down the 9 mg kg^{-1}dosage of caffeine that was the protocol when the study originated.

APPENDIX A

OPERATIONAL DEFINITIONS, DELIMITATIONS, SIGNIFICANCE OF THE STUDY, HYPOTHESIS

Operational Definitions

Aerobic Bench Stepping: A form of aerobic exercise that combines aerobic dance and bench stepping on a 6 to 8- inch bench at a cadence of 118 to 130 beats.min^{-1}.

Cadence: Often referred to as beats per minute. Aerobic dance bench stepping is often performed at 118 to 130 beats.min^{-1}

Rate of Perceived Exertion (RPE): RPE often measures the feeling that one has while engaging in aerobic exercise, quantifying that feeling by a number. The Borg's scale, a scale of 16-20 with 16 being very light and 20 being extremely hard, is the scale most often used.

Caffeine: The most widely used psychoactive drug. Caffeine is often found in soda, tea, coffee, chocolate, and various medications.

VO_2 Max: The individual's maximal rate of oxygen consumption that can be maintained at a maximal workload. The average VO2 max for the age group being tested (18-22) is aVO_2 max of 31-37.9 ml0_2/dl (ACSM-Standards for evaluating aerobic fitness.).

Delimitation

The study will be delimited to a majority of female subjects ranging in ages from 18-22. These subjects will have aerobic dance bench stepping (ADBS) experience due to the Physical Fitness and Wellness

(PFW) class they are enrolled in. The testing conditions are delimited to ADBS at cadences of 128 beats.min^{-1} and bench heights of 6 inches. The study will be limited to 30 subjects. The testing conditions will be limited to a lab setting, which will enable the principle investigator to use lab equipment to measure heart rate (HR), oxygen consumption (VO_2), REE, RER, and rate of perceived exertion (RPE).

Significance of the study

Exercising at 50 – 85% VO_2R for 20 to 60 minutes 3 to 5 days per week is critical for enhancing aerobic fitness and maintaining a healthy body weight (2). Methods employed to ensure optimal exercise intensity include exercising at 50 – 85% heart rate reserve and/or an RPE of 12-14 (39). Limited research suggests that caffeine consumption affects HR and RPE responses to exercise. As a result, one's ability to accurately monitor exercise intensity, using the HR and RPE methods, following consumption of caffeine is questionable. Most research on the effects of caffeine on the monitoring of intensity of aerobic exercise has been limited to elite athletes on athletic type events (1, 7, 13, 19, 26, 27, 42). However, caffeine consumption is rampant among people of all ages and all levels of fitness (17); moreover, elite athletes often abstain from caffeine during intense training (1, 13, 19, 26). Of major significance in this study is whether caffeine alters the ability to accurately monitor intensity of aerobic exercise in non-elite athletes. Research previously has eluded to varying effects of caffeine on elite athletes during running, cycling, swimming, and rowing (1, 7, 13, 19, 26, 27, 42); however, there is no current research that shows effects of caffeine on people of average fitness (VO_2 max of 31-37.9 ml0_2/dl). The present study will examine the effects of caffeine (3 -6 mg·kg^{-1}) on the monitoring of intensity of aerobic exercise (ADBS).

The results of this study may prove to be useful to people of average fitness (VO_2 max of 31-37.9 ml0_2/dl), who engage in regular aerobic exercise (3-5 days per week). Recommendations for beginning an exercise program are related to the increase in many health benefits (40). As an individual enters a program, if it was possible for them to feel as though they were working at a lessened rate, they could possibly increase the duration and frequency of the exercise session and capitalize on the health related benefits. Research has been inconsistent in showing that caffeine lowers the rate of perceived exertion (RPE) in individuals, of average fitness levels (VO_2 max of 31-37.9 ml0_2/dl), engaging in aerobic exercise. Frary et al. (17) have shown trends in caffeine consumption to be greatly increasing, which leads to the conclusion that people who are exercising regularly are among the group of caffeine consumers. If the hypothesized results remain, then the consumption of moderate (3 mg kg^{-1}) to moderate amounts (6mg kg^{-1}) of caffeine can be shown to decrease RPE among people engaging in aerobic exercise.

APPENDIX B

REVIEW OF LITERATURE

Review of Literature

Caffeine is consumed in large quantities by people of all ages (17). In a representative sample of the US population (n=18,081, 2 yr of age and older), 87% (n=15,716) consumed food and beverages containing caffeine. Based on age, 93% of the adult males and non-pregnant females (18 years and older) and 80% of children and adolescents (2 to 17 years of age) consumed caffeine. On average, caffeine consumers' intakes were 193 mg of caffeine per day (~1.2 mg kg^{-1} day^{-1}), with adults consuming more than 240 mg of caffeine per day (~1.5 mg kg^{-1} day^{-1}) and children and adolescents consuming almost 30 mg per day (~.4 mg kg^{-1} day^{-1}). In contrast, a previous study reported that mean caffeine intake of 243 adults was approximately 280 mg per day (~4 mg kg^{-1} day^{-1}) (4). In another study, the average intake of 202 adults surveyed was 186 mg day^{-1}(28). Despite the discordance in the literature, it can be assumed that more than 4 out of 5 adults in the U.S. consume caffeine and that adult caffeine consumption approaches, if not exceeds, 200 mg per day.

People of all ages consume caffeine-containing beverages for a variety of reasons. For example, people drink coffee to stay awake, in social settings, and perhaps in preparation for exercise (29, 32). Apart from the popular attractions to caffeine such as enhanced attention (14, 44), reduced reaction time (29), and improved timing behavior (14) there are three main physiological mechanisms that enable caffeine to boost alertness and exercise performance. The first physiological mechanism is the blocking of adenosine (12, 44). Increased levels of adenosine result in increased sleepiness, reduced arousal, and suppression of spontaneity (12). Increasing the levels of free calcium ions in muscle fibers (47) is the second physiological attribute. With increased calcium ions, there is increased effectiveness in each muscle contraction (25, 27). The final physiological attribute is that caffeine administration leads to increases in the circulation of epinephrine during dynamic exercise (3, 12, 21, 34, 42, 46). Increased epinephrine increases plasma glucose which leads to glycogen sparing (42).

Although there are more than 1,000 proprietary drugs that list caffeine as an ingredient (FDA's National Center for Drugs and Biologics), the most popular sources of caffeine are coffee, soft drinks, and tea (17). In the study by Frary et al. (17), coffee, soft drinks, and tea contributed 71%, 16%, and 12%, respectively, to the average daily caffeine intake of the caffeine consumers, age 2 years and older, sampled. Specifically, caffeine consumers averaged 136, 31, and 23 mg per day of caffeine from coffee, soft drinks, and tea, respectively. However, when limited to children and adolescent (2 to 17 years of age), soft drinks were the primary source of caffeine. For comparison, an 8-oz cup (240 ml) of coffee contains about 100 mg of caffeine (4), whereas, caffeinated soft drinks and brewed tea of equivalent sizes contain less than half of the caffeine found in coffee (i.e., approximately 24 mg and 35 mg of caffeine per 8-oz serving, respectively (4).

The popularity of soft drinks as the primary caffeine choice among young adults has also been observed in a small sample of college students (n=30) (29) In this study, ingestion of caffeine in the form of soft drinks, tea, and coffee averaged 120 mg per day, most of which was in the form of soft drinks. Soft drink consumption ranged from 1.2 to 1.6 12-oz cans per day while tea consumption ranged from .6 to 1.3 12-oz servings a day and coffee, comprising the smallest amount of caffeine consumption, was .2, 8-oz cups daily average.

Trends in caffeine consumption have changed during the last three decades. Between 1973 and 2003, coffee consumption has declined by 38% (25.8 to 18.6 gallons per capita per year) whereas soft drink consumption has increased by 68% (27.7 to 46.4 gallons per capita per year) (50). Such a shift may be contributed, at least in part, to an increase in soft drink consumption among children and adolescents. For instance, from 1977 to 1998, soft drink consumption in children has increased by 48

% (18). Mean daily consumption of soft-drinks in children has more than doubled from 5 fl. oz. to 12 fl. oz. per day (18).

Undoubtedly, caffeine is the most popular drug in North America (17). The most commonly purported reasons for caffeine consumption include morning and early afternoon stimulation when diurnal arousal is low (4, 9) and enhancement of physical activities, such as long distance running, sprinting, cycling, and rowing (1, 5, 7, 13, 27, 42). With caffeine consumption at an all time high, there is a need to review caffeine's impact on performance, esp. caffeine's impact on performance of habitual users of caffeine. Using relevant literature, the purposes of this review are to discern whether: 1) caffeine enhances key elements of performance, such as alertness, reaction time, anaerobic power, and aerobic capacity; 2) caffeine effects the ability to properly monitor exercise using common procedures (i.e., heart rate and perception of effort); and 3) habitual use of caffeine attenuates its impact on performance and the monitoring of exercise.

Theorized Physiological Effects of Caffeine

Many mechanisms to explain caffeine's effects on the body have been theorized. To date, no theorized mechanism has been substantiated. This section will discuss in detail the most commonly purported mechanisms of caffeine.

Methylaxantline, or more commonly referred to as caffeine, is a central nervous system stimulant. Methylaxantline is an adenosine receptor blocker (12). In short, adenosine is a normal cellular constituent that is regulated mainly by ATP metabolism and other adenine nucleotides (12). Adenosine receptors are a G-protein coupled family of receptors that either inhibit or A_1 or stimulate A_2 adenylate cyclase. Adenosine stimulation of hepatocytes has been found to increase glycogen resynthesis; however, increases in adenosine are associated with increases in cAMP, which would lead to stimulation of glycogen breakdown (44). Adenosine concentrations increase with muscular contractions during the time the body is awake and naturally decrease with sleep. With increased levels of adenosine, reduced arousal, increased sleepiness, and suppression of spontaneity becomes present (12). Because caffeine acts as a central nervous system stimulant (31), it blocks the inhibitory effects of adenosine, increasing one's ability to excite a motor unit pool (30). The blocking of adenosine receptors in the brain also causes cholinergic stimulation and the reversal of dopaminergic deficiencies, which can lead to a decreased RPE during physical activity (26, 32).

Caffeine supplementation has also been associated with increasing the levels of free calcium ions in muscle fibers, either by increasing the release of calcium by the sarcoplasmic reticulum or decreasing the rate of calcium re-uptake (47). Elevated calcium levels increases the action of the actin and myosin binding with in turn leads the more effective muscle contraction (25, 27). Physiological doses of caffeine potentiate muscle force out put during low stimulation frequency exercise (45). The fact that caffeine only potentiated the low (20 Hz) and not the high (40 Hz) stimulation frequency muscle contraction force likely relates to the mechanism of low frequency fatigue and to the action mechanism of caffeine (45). Low frequency stimulation is felt to result in a reduction of muscle fatigue due to the impairment of excitation contraction coupling (E-C coupling) (48).

Caffeine administration leads to increases in the circulation of epinephrine during dynamic exercise (3, 12, 20, 34, 44, 46) Generally, it is thought that an increase in the circulating concentrations of epinephrine contributes to the ergogenic effect of caffeine (20). Increases in epinephrine mediated by caffeine, could lead to an increase in plasma glucose (42). Such an increase in glucose could contribute to the glycogen sparing (42).

Epinephrine can have many diverse metabolic effects, including stimulation of hepatic glycogenolysis, adipocyte lipolysis, and skeletal muscle glycogenolysis (3). With increase levels of epinephrine in the blood, there would be a greater stimulatory effect on Na-K pump activity and increase resistance to skeletal muscle fatigue (34). While in contrast, Fisher et al. (16), found increased levels of nor-epinephrine in caffeine users after 60 minutes of exercise and Tarnopolosky et. al (45) found no changes in epinephrine or norepinephrine after 90 minutes of exercise post consumption (45). Epinephrine may stimulate skeletal muscle metabolism by activating glycogen phosphorylase, which leads to an increasing rate of anaerobic glycolysis and ATP production (11, 22). Much of the literature suggests that there are no effects on maximal voluntary contraction or muscular endurance, however; the differences in time and amount of caffeine consumption make interpretation of the results more difficult (10). Kalmar et al (30), stated that caffeine does increase the activation on voluntary motor units as well as an increased ability to sustain sub-maximal voluntary contractions.

Psychomotor performance

One of the most commonly reported reasons for caffeine consumption is to increase alertness and enhanced thought processes

(44) Caffeine has been examined closely to determine if there is a direct relationship between caffeine consumption and accuracy of time estimation. As early as 1912, Hollingsworth noted that 65-130 mg of caffeine appeared to enhance typing speed, and a dose of 390 mg resulted in poor motor performance and tremor (24). Stine et al. (44), participants' who reported low or moderate amounts of caffeine consumption (< 135 mg daily) were the most accurate in their time estimations when compared to individuals reporting no caffeine or high amounts of daily caffeine (> 135 mg daily).

Caffeine has been shown to enhance vigilance, cognition, and psychomotor performance, while reducing reaction time (9, 12, 33). Kruk et al. (33) showed that in a thermo-neutral environment, caffeine ingestion (5mg) improves psychomotor performance during aerobic exercise. Durlach et al. (14), evaluated how quickly after consumption, caffeine's impact on reaction time could be detected. The subjects (n=82) were asked to refrain from caffeine consumption after 6:00 pm the day prior to the study. Two dependant variables were measured with a key-press apparatus: reaction time and movement time. The authors gave evidence that the participant was less distracted by the distracter and quicker to depress the correct key if they had consumed caffeine although the final conclusion failed to be statistically reliable.

Caffeine has also been linked to an increase in attention and alertness (27, 33, 41, 44). Rogers et al. (41), suggested that caffeine increased self-rated alertness of both caffeine consumers and non-consumers. The purpose of this study was to determine if the positive effects were associated with actual caffeine consumption or were they linked to withdrawal from a habitual caffeine user. The authors showed that prior to receiving caffeine, regular caffeine consumers who were in withdraw were less alert and more tense than the participants that were non-consumers (41). After caffeine intake, the habitual users showed significant improvements in both mood and psychomotor aspects. Caffeine increased self-rated alertness in both the habitual caffeine users and the non-habitual users; however, some of the non-consumers performance decreased following ingestion. These results suggest that the psycho-stimulant's, caffeine, effects are largely related to withdrawal reversal (41).

Aerobic Performance

A number of researchers often measure endurance or aerobic based exercise because power is kept constant and exercise time can be quantified. (15, 21, 27, 40, 42) Numerous studies have supported the idea that caffeine ergogenically effects aerobic exercise. (1, 5, 30, 34, 45) Anderson et al. (1) concluded that caffeine consumption prior to an endurance based exercise bout enhanced performance of a 2000-M row; more specifically, the first 500 m. In concordance with the results of Anderson et al. (1), it has been suggested that caffeine ingestion also increased exercise time to exhaustion (38) and an increase in work output at the same RPE as a placebo (3). Not all studies have been able to show that caffeine enhances aerobic performance (7, 14, 25, 27, 42). For example, Hermann et al. (25), administered a single dose to (5 mg kg^{-1}) 8 sedentary men. Caffeine was consumed 60 minutes prior to exercise. The subjects then completed two 60 treadmill-walking exercises, one at 30% $V0_2$ max and the other at 50% VO_2 max. The authors concluded that ingestion of the given amount of caffeine did not provide a caffeine induced shift in energy substrate usage. Caffeine did not prove to be an effective means for energy cost on prolonged walking (25).

Monitoring Intensity

Rate of Perceived Exertion

If an individual is able to feel that less effort is being exerted, then they may be able to work at a higher intensity for a longer period of time (7). The Borg 15-point rating scale (RPE) was introduced to integrate body signals, perceptions, and experiences into a subjective rating of exertion (40). The use of RPE has been shown to be a valid and reliable way to measure intensity in males and females under 35 years of age (40). A reduction in RPE or an increased intensity at the same RPE may be caused by a decrease in neuronal activation threshold of motor neurons and/or alterations in muscle contraction force caused by caffeine supplementation (13). These changes would in turn result in an attenuation of muscle sensory processing that would reduce RPE because of more motor units being recruited and greater amounts of force for a given task (13).

Birnbaum et al. (7), reported a significant reduction in the rate of perceived exertion. Ten college students were asked to perform 2, 30-minute runs on a treadmill at 70% of max, 1 trial post caffeine consumption and the other trial post placebo consumption. The caffeine and the placebo trials produced a mean RPE of 10.8 and 11.2, respectively. Although the Borg's scale is measured in whole numbers, the difference is significant and related the idea that subjects while under caffeine influence, were performing the same tasks with lessened discomfort. Gastin et al. (19), studied eight moderately trained runners who were selected for their limited daily caffeine usage. During the investigation they were given either a caffeinated substance (5 mg kg^{-1}) or a placebo and asked to run on a treadmill until exhaustion. Upon completion of the caffeine trials, subjects reported significantly lower RPE values however, exercise performance was not improved. While many studies have determined that the best ergogenically enhanced effect comes from moderate amounts of caffeine (3 mg kg^{-1}) (11, 16, 29, 30, 33, 38, 45, 46), McNaughton (35), found that the lowest RPE rating came from the largest doses (9 mg kg^{-1}). This study studied treadmill running of only 70-75% of maximal oxygen consumption and found that the more caffeine that was ingested, the lower the RPE. Doherty et al. (13), tested RPE (Borg's scale) at 30s, 60s and 120s during a constant rate test (100% maximal effort). RPE was lower by approximately 1 point in the caffeine trials as opposed to the placebo trials. The improvement in performance may be concluded to the reduction in RPE during the constant rate phase or because of the increase in post-exercise blood lactate levels (13).

Heart Rate

Heart rate is on of the most widely used forms of monitoring the intensity of exercise. Heart rate is often taken prior to exercise, during exercise, and post exercise. Heart rate is a non-invasive intensity monitoring strategy used by many people; however, it is subject to much human error if palpated by the individual (40). Much of this human error is attributed to either incorrect counting or the fact that heart rate recovers faster after less strenuous exercise as opposed to more vigorous exercise

(40). Heart rate is often affected with the administration of caffeine prior to exercise. Hunter et al. (27), recorded instantaneous output, heart rate, and RPE at every 500-m split. Seven of eight participants correctly identified when they had taken the caffeine supplement in lieu of the placebo, citing symptoms of reduced concentration and elevated heart rates before, during, and after the trial. The mean heart rates were significantly higher in the caffeine enhanced group as opposed to the placebo, 181.6 +/- 1.9 and 175.5 +/- 2.7 bpm, respectively. The authors found that, in contrast to the large ergogenic effect measured in open-ended trails, caffeine did not significantly enhance overall performance during the bouts of high intensity exercise. In contrast to these results, Roy et al. (42), reported that caffeine had no apparent effects on VO_2 or heart rate. The blood samples also showed no affects to plasma glucose or other serums in the blood. Blood glucose stayed constant between both trials (42). Nishijima et al. (36), also reported no significant differences in heart rate between the placebo and caffeine groups (36). Birnbaum et al. (7), showed that heart rate was actually increased in the placebo trial as related to the caffeine trial, 160 bpm and 157 bpm, respectively. Non-habitual users of caffeine are often affected differently upon administration. Heart rate measurements were taken post consumption at 1 hour, 3 hours, and 6 hours on subjects who were non-users of caffeine during exercise at 50%-80% of maximum heart rate exercise. The subjects showed increased heart rates with time under the influence of caffeine when compared the non-enhanced trials (5).

<u>VO_2</u>

Much of the research concerns subjects working at a given workload based on their VO_2 max. Fisher et al. (16), had subjects run at 75 % VO_2 max, Bell et al. (5), had subjects work at 80% VO_2 max, Roy et al. (42), had subjects exercise at 65% VO_2max, and Engels et al. (15), had subjects exercise at low (30% VO_2 max) and moderate VO_2 max (50%) values.

Although many studies test for VO_2 changes, many studies failed to find changes in VO_2, ventilation, blood pressure (BP), or heart rate (HR)(7, 8, 19, 45). For example, Tarnopolsky (45), tested male runners at 70% VO_2 max and found no statistically reliable changes in VO_2, HR, or RPE. Bond et al. (8), tested to maximal exertion and found no significant changes in VO_2, HR, or V_E Birnbaum et al. (7), provided evidence in the conclusion of the testing that there were no significant differences in the cardiovascular responses or respiratory responses; however, the authors provided that it is unlikely that caffeine provides an improvement in energy expenditure during moderate exercise since VO_2, HR, and BP were unchanged.

However, Birnbaum et al. (7), did find increases in T_V and V_A and stated that it is reasonable to conclude that caffeine has a small but significant effect on pulmonary function during sub-maximal exercise. The combined increase in T_V and V_A could be explained by caffeine's ability to produce bronchodilation, and is directly related to the subjects decreased RPE (7). As ventilation efficiency improves, the RPE of a subject decreases. The increase in V_A, in particular, indicates that inspired air reaching the alveoli and participating in gas exchange helped to ensure consistency in arterial blood gases, which could otherwise compromise the respiratory response function (7). The lack of differentiation in VO_2 and RER values in the Engels et al. (15), research suggests that caffeine had no effect on the total energy cost. In the sub-maximal test performed by Hermann et al. (25), caffeine had no significant effects on oxygen uptake or RER values. On the other hand, average exercise minute ventilation was 1.27 L min $^{-1}$ higher in the caffeine trial as opposed to the placebo trial.

Conversely, Nishijima et al. (36) reported that at rest VO_2 and respiratory gas exchange ratio showed no significant difference between groups and trials. During the exercise period, VO_2 values significantly increased ($p<.001$) in both trials when compared to resting. Although Gastin et al. (19), found no change in VO_2, there were significant increases in minute-ventilation VE during the 3-minute sub-maximal exercise bout (19).

In each study, researchers had subjects exercise at a given % VO_2 instead of at a given VO_2. By holding % VO_2 constant across trials, by definition, oxygen consumption will not change, and it is therefore impossible to detect whether oxygen consumption is affected by caffeine. Instead, to test whether caffeine effects oxygen consumption a constant workload should be employed to allow oxygen consumption to vary.

Time of Caffeine Consumption

It is reasonable to assume that the ingestion of caffeine before moderate exercise might enhance both fat oxidation and activity in the autonomic nervous system (36). Although caffeine has a half-life 4-6 h, this implies that large quantities would stay in the blood for 3-4 h after ingestion, thus most studies focus on up to 1 hour after consumption (5). Previous research dealing with the ergogenic effect of caffeine on aerobic performance is fairly inconsistent concerning the time interval between the administration of the caffeine treatment and the exercise test performance. There are many discrepancies in the literature on the best time to ingest caffeine. The ergogenic effect of caffeine is said to occur from 30-60 minutes post consumption (3, 14, 30, 34, 38, 46). In conjunction to the consumption window (30-60 minutes), Durlach et al. (14) studied the key-press test which was given 40 minutes post consumption. Jacobsen and Edgley, reported beginning testing 45 minutes post consumption to aid in caffeine absorption. Doherty et al. (13), Birnbaum et al. (7), and Lindinger et al. (34), concluded that 60 minutes provided sufficient time for the absorption of the caffeine in their research.

Different studies used a different treatment protocol (ingestion outside the 30-60 minute window) that ultimately resulted in positive outcomes (5, 36, 42, 46). For example, Bell and McLellan (5) demonstrated that a 5 mg kg^{-1} dosage of caffeine administered 1 hr., 3 hr., and 6 hr prior to testing showed that both the magnitude and duration of the ergogenic effect of the caffeine was greater in non-habitual users as compared to habitual users. In agreement to Bell and McLellan (5), Nishijima et al. (36) had subjects ingest caffeine supplement 120 minutes prior to the given exercise. A caffeine-induced enhancement of the ANS (autonomic nervous system) was observed at 2.5 hours post consumption.

Dose of Caffeine

There has been an almost unequivocal support for the beneficial effects of oral caffeine ingestion (3-9 mg kg^{-1}) (11, 13, 16, 29, 30, 33, 38, 42, 45, 46). One problem with generalizing from many laboratory studies to real-life is that they often use a single large dose of caffeine (often equivalent to an individual's total daily intake). Caffeine is not usually ingested in this approach; rather it is ingested in several small doses throughout the day. The aim of the study by Brice et al. (9), was to study the effects of caffeine on activity when given in small "normal" doses (9). There were five periods of caffeine ingestion- 200 mg at 1:00 pm and four 65 mg doses consumed at 10:00am, 11:00am, 12:00 pm, and 1:00 pm (9). Hunter et al. (27) also used the small incremental consumption protocol. The day of testing, subjects either ingested gelatin capsules containing placebo (white flour) with 150 ml of either a sports drink (7% carbohydrate), or a gelatin capsule containing caffeine (6 mg kg^{-1}) with the 7% carbohydrate solution. Because caffeine is excreted easily in sweat, the participant consumed a maintenance dose (0.33 mg kg^{-1}) every 15 minutes during the trail (27).

Many studies have used the consumption protocol of a single large dose prior to testing and had positive effects (11, 16, 29, 30, 33, 38, 42, 45, 46). The optimal dose has not been determined because it may vary according to the individual's sensitivity to caffeine (5). The normal protocol in caffeine testing is either: 1) milligrams of caffeine according the body weight (kg) of the subjects, or 2) simply an absolute amount for every subject. Nishijima (36) chose to use a single dose of 300 milligrams of caffeine supplemented with 100 ml of water and concluded that the use of caffeinated beverages can be useful when prescribing exercise to individuals with a depressed autonomic nervous system. Bangsbo et al. (3), used 500 mg, Rogers et al. (41), used either 50 mg or 100 mg. Absolute dosages provided positive results in these studies.

Measuring the amount of caffeine consumption by the individual's weight also proposed positive effects. Birnbaum et al. (7), used a larger amount at 7 mg kg^{-1} of body weight of the individual, and while there was no difference in cardiovascular responses, respiratory responses with the exception of TV and VA, there was a significant difference in RPE. In contrast to the most often used amount of 3-6 mg kg^{-1} (11, 16, 29, 30, 33, 38, 42, 45, 46), Jacobsen and Edgley (29) stated that there were no visible effects from caffeine on reaction time unless the amount exceeded 3 mg kg^{-1}. In support, Graham (20) stated that the optimal dose lies in the lower range (3-6 mg kg^{-1}) because these doses produce equivalent ergogenic effects to the higher doses (20) and not in the higher doses of 9 mg kg^{-1} that both Graham (21) and Spriet (43) had subjects consume.

Yeomans' (50) subjects ingested 1-2 mg kg^{-1} of caffeine following a meal and tested for reaction time and 60 minutes later tested again by the same methods (50). The small amounts of caffeine in this study produced reliable improvements in performance on a sustained attention task, and increased rated mental awareness. In contrast, Lindinger et al. (34), stated that the effect of caffeine is most pronounced at the high dosage of 9 mg kg^{-1} (34). Spriet et al. (43), stated that the high dosage of 9 mg kg^{-1} decreased muscle glycogenolysis by 55% in the initial 15 minutes of exercise The spared glycogen is available during the later stages of exercise, resulting in a prolonged time to exhaustion (43).

Training Levels of Subjects

Much of the research on the effects of caffeine on aerobic exercise to date includes subjects of high fitness levels (> 37.9 $ml0_2$/dl). There is little research on subjects with average fitness levels (VO_2 max of 31-37.9 $ml0_2$/dl) (ACSM). For example: Kruk et al. (33), used 9 male professional soccer players, Doherty et al. (13), used 11 trained cyclists, Roy et al. (42), used seven males and five females that were endurance-trained athletes, and Hunter et al. (27), used 8 highly trained individuals who were accustomed to long durations of exercise. Roy et al. (42), used only subjects who had a minimum VO_2 max 50 $ml0_2$/dl and 60 $ml0_2$/dl for females and males, respectively (42). It is difficult to compare the possibilities of positive caffeine induced effects of people of average fitness, with the results of these studies combined.

The studies that have used subjects with either average or low fitness levels, have been tested on reaction time, mental capacity, and psychomotor capabilities not aerobic performance (9, 36).

Habitual versus Non-habitual Users

It has been reported that there is a greater longer lasting ergogenic effect of non-user of caffeine versus regular users of caffeine. The non users of caffeine experience a greater blocking of the adenosine receptors which in turn leads to a greater ergogenic effect (5). Yeomans reported that consumers who were in caffeine withdrawal had significantly improved performance in reaction time and other mental tasks. In contrast, Graham (21) and Spriet (43), had both consumers and non-consumers ingest 9 mg kg^{-1} of caffeine. Bell et al. (5), have also mentioned that a greater ergogenic response during exercise to exhaustion at 80% VO_2 Max for users when compared to non-users (5). One might expect that the ergogenic response would be greater for users after a large quantity of caffeine (9 mg kg^{-1}), however the dose- response relationship between caffeine and exercise performance has yet to be clarified for users and non-users of the drug (5).

The fed state

A component mentioned in much of the research is the fasting state of the individuals being tested. Almost always, participants were asked to abstain from caffeine use at least in the 24 hours prior to testing (9, 13, 27). However, Fisher et. al., instructed subjects to abstain from caffeine use for 6 hours prior to testing and had positive results due to the withdraw (16). With this factor involved, the concept of caffeine withdrawal came into view. Brice et al. (9), studied, participants who were asked to maintain normal daily activities with a journal of what they had eaten prior to the test. They were asked to abstain from caffeine intake (9).

Summary and Conclusions

Recommendations for beginning an exercise program is related to the increase in many health benefits (40). As an individual enters a program, if it was possible for them to feel as though they were working at a lessened rate, they could possibly increase the duration and frequency of the exercise session and capitalize on the health related benefits.

Because of the popularity of caffeine worldwide (44), it is imperative that the influence of caffeine on exercise be examined on individuals of average fitness. It can be concluded that apart from popular belief, caffeine does not raise heart rate during exercise of habitual users of caffeine. Although caffeine is dependence producing (44), Caffeine has been shown to decrease the rate of perceived exertion (RPE) (1, 7, 27, 40). There is a gap in the research when concerning people of average fitness levels and the use of caffeine as a positive influence on the individual's perception of intensity during sub-maximal aerobic exercise. Apart from the exercise-induced actions, caffeine is of great use when the enhancement of attention or a reduction on reaction time is needed (14, 26, 29, 33, 44) Caffeine as a whole, when used moderately, 3-6 mg kg^{-1}, can have positive effects on the body and on the perception during exercise.

APPENDIX C

INFORMED CONSENT

Consent Form

Project Title:	The Effects of Caffeine on Monitoring the Intensity of Aerobic Exercise.
IRB Number:	
Principal Investigator:	Jennifer N. Ahrens

INTRODUCTION

You are asked to take part in a research study at Texas State University-San Marcos. This study will investigate the effects of caffeine on the monitoring of intensity during aerobic exercise. The purposes of this study are to discern whether: 1) caffeine enhances key elements of aerobic performance, such heart rate, and perception (RPE). and 2) determine the effects of caffeine on the ability to properly monitor exercise using common procedures (i.e., heart rate and perception of effort). This study will also determine whether moderate or large dosages of caffeine impacts the monitoring of exercise. I am a graduate student and a graduate assistant at Texas State University- San Marcos, in the Health Physical Education and Recreation Department. I am performing this study to fulfill my thesis requirement. I hope to learn that caffeine lowers the rate of perceived exertion allowing individuals to exercise at a higher intensity. Read this form and ask questions about anything you do not understand before you decide if you want to participate.

PURPOSE OF THIS RESEARCH STUDY

This 4-visit research study may give insight to the fact that caffeine allows one to exercise at a lower RPE.

PROCEDURES

If you agree to participate in this research study, you will be expected to do the following things:

1. Before the actual data collection begins, you will meet with a staff member at Texas State University for 45 minutes to do the required fitness testing and complete the initial training of the moves in the ADBS video. At the initial visit You will be expected to:
   - Fill out several forms about your health history, contact information, and the current caffeine consumption questionnaire.
   - Be measured for body weight and height
   - Be measured for VO_2 Max on a treadmill
2. Have your doctor or a health care facility sign a medical approval form if you:

- Have a disease of the heart, lung, liver, or kidney,
- Have diabetes,
- Are pregnant,
- Have experienced one or more of the following:

  - pain or discomfort in the chest, neck, jaw, arms or other areas;
  - unusual shortness of breath at rest or with mild activity;
  - dizziness or fainting;
  - difficulty breathing while lying down or sleeping;
  - ankle swelling;
  - rapid or pounding heart beats; or
  - periodic numbness/pain in the arms or legs.

3. If you have none of the diseases or conditions listed above, then you can sign a form that says you want to participate without getting written approval from a health care professional. Note: You cannot take part in this study unless you have written medical approval or a signed waiver.

POTENTIAL RISKS OR DISCOMFORTS

This study may involve a few risks to your health:

- There exists the possibility of certain changes occurring during walking, yoga, and graded maximal exercise test. These include abnormal blood pressure, fainting, irregular, fast, or closing heart rhythm, and in rare instances, heart attack, stroke, or death. Although there has been no research identifying a college-age student's risk of death during graded maximal exercise, the studies on the risk of death during graded maximal exercise for middle-aged men is 1 death per 10,000 tests. Every effort will be made to minimize these risks by evaluation and preliminary information relating to your health and fitness and by careful observations during testing. In addition, emergency equipment is located nearby in the athletic training offices and is available at all times. You also may experience slight soreness that will lessen within a few days.

- To ensure your safety, you must tell us about your current health and health history during the first meeting.
- Your personal information will be kept confidential. Your file will be kept in a locked cabinet. The professors and staff will use this information for research, but your name will not be given out in any reports. With your written consent, personal information regarding your health may be shared confidentially with the referring health agency.
- This study involves no special risks to women of childbearing age. In fact, studies show that moderate exercise and a

healthy diet can help control blood sugar and improve pregnancy outcome.

POSSIBLE BENEFITS

This study will test your VO_2 max and allow you to now your current level of fitness. This is a test that is an effective measure of VO_2 max and that usually costs money. This study will provide insight to the understanding that caffeine either enhances your aerobic performance or hinders you.

You will have the opportunity to be part of empirical research, that will answer questions that have yet to be answered through research.

CONFIDENTIALITY

Your identity in this study will be kept private. The results of the study may be shared for scientific purposes but we will not give your name. When the results of the research are shared, no information will be included that would give away who you are. If photographs, videos, or audiotape recordings of you are ever used, your name will not be included. However, as a result of your participation in this study, your file may be seen by any relevant governmental agency (e.g., Texas Department of State Health Services), by the Texas State University-San Marcos Institutional Review Board, or by the persons doing this study. Your records will be kept private as much as the law requires. If you give us permission, your information may be shared with your health care provider. Personal information will be stored in a locked file cabinet for five years, after which, it will be destroyed. We will ask for additional written consent from you if this data will be used for other research purposes.

TERMINATION OF RESEARCH STUDY

You are free to decide if you would like to take part in this study. If you choose not to take part, it will not affect your grade. You may quit at anytime. If you decide to stop participating in the study, please notify myself or Lisa Lloyd Ph.D. immediately. In addition, the researchers may end your participation in the study without your consent if they believe that you may be in danger (i.e., based on physical symptoms experienced during exercise classes such as pounding heartbeat, difficulty breathing, etc.) or if your physician or referring health care professional feels that exercise is not safe for you.

AVAILABLE SOURCES OF INFORMATION

For questions about this study call:

Principal investigator: Jennifer Ahrens

Phone Number: 512-245-1971

For questions you may have about your rights as a research subject call:

Thesis Chair: Lisa Lloyd, PhD

Phone Number: 512-245-8358

AUTHORIZATION

"I have read and understand this consent form, and I agree to participate in this research study. I understand that I will receive a copy of this form. I voluntarily choose to participate, but I understand that my consent does not take away any legal rights in the case of negligence or other legal fault of anyone who is involved in this study. I further understand that nothing in this consent form is intended to replace any applicable Federal, state, or local laws. I also understand that I may withdraw from this study at any time without penalty."

Participant Name (Printed): ______________________________
Date: ____________

Participant Signature: ______________________________

Date: ____________

Principal Investigator Signature: ______________________________

Date: ____________

Witness (Signature): ______________________________

Date: ____________

APPENDIX D

SYNOPSIS of STUDY

Synopsis of Proposal

The Effects of Caffeine on the Accuracy of Monitoring Exercise Intensity

1. Participants (n~30) will be recruited from students (n~120) enrolled in Physical Fitness and Wellness (PFW) 1110A Aerobics offered during Summer I of 2005 at Texas State University. Typically, PFW 1110A students are young Caucasian-nonhispanic females, 18 to 22 years of age. However, apparently healthy female and male volunteers of all ethinic backgrounds and who are younger than 55 and 45 years of age, respectively, will be encouraged to participate in this study.

   This study is intended for apparently healthy adults exhibiting no signs or symptoms suggestive of heart, metabolic (diabetes), and pulmonary disease. To identify who should not participate in the study, a comprehensive health-history survey will be administered to identify volunteers who: 1) have heart disease, diabetes, chronic obstructive pulmonary disease (including severe asthma), 2) have experienced recent musculoskeletal injuries, and 3) are pregnant (or think they are pregnant).

2. At the beginning of Summer I, Jennifer Ahrens will inform potential participants enrolled in two 1110A classes about the components of the study. Extra credit will be offered for those who volunteer to participate (*Note.* An alternative opportunity for students who are not

interested in participating in the study will be offered). Interested participants will be instructed to sign up for an initial visit to the lab. They will be given pre-test instructions instructing them, prior to each lab visit, to abstain: 1) from food and beverages for 1 to 2 hours, 2) tobacco products for 3 hours, and 3) alcohol and caffeine for 48 hours. During the first visit, participants will be given an informed consent to read, be given the opportunity to ask questions about the study, and will be asked to sign the informed consent if they would like to proceed with participation in the study. (*Note*. The reviewers of this proposal are directed to the informed consent for a complete description of the study's methodology). Briefly, each subject will visit the laboratory on three different occasions. During visit #1, subjects will: 1) sign informed consent, 2) complete health appraisal, 3) complete caffeine intake and physical activity questionnaires, 4) be measured for height and weight, and 5) be measured for VO_2 Max. For the second, third, and fourth visits to the lab, subjects will be given either a dose of caffeine (3 mg kg^{-1} or 9 mg $kg^{-1)}$ or a placebo, and instructed to rest for 45 minutes. After 45 minutes following the consumption of caffeine, subjects will be fitted with a heart rate monitor and mouthpiece (connected to a metabolic cart) and, then, asked to follow an 8-minute video-taped aerobic dance bench stepping routine.

3. The potential risks of the study are minimal. The most common risks during exercise testing are delayed onset muscle soreness and/or fatigue. Although there has been no research identifying a college-age student's risk of death during graded maximal exercise, the studies on the risk of death during graded maximal exercise for middle-aged men is 1 death per 10,000 tests. In rare cases, people experience heart attack, stroke, or death during exercise. Every effort will be made to ensure that the participants are safe. We will let them know that if they experience a very fast heart rate, very slow heart rate, a pounding sensation in their chest, chest pain, pain in their arms, dizziness, or difficulty breathing, to stop exercising and notify the test administrator immediately. The test administrator will contact call 911 if needed. It is important to note that the intensity and duration of the exercises, other than the maximal testing, that will be used in this study are no greater than that employed during typical group exercise (e.g., aerobic dance bench stepping) classes. During exercise, it is normal for heart rate and breathing rate to increase and for sweating to occur.

To ensure participants' safety, the following statement will be included in the informed consent: "This study is intended for apparently healthy male and female adults exhibiting no signs or symptoms suggestive of heart, metabolic (diabetes), and pulmonary disease. If you have been diagnosed with heart disease, diabetes, and chronic obstructive pulmonary disease (including severe asthma), have recently experienced a musculoskeletal injury, have been told by a health care provider to not exercise, or are pregnant (or think that you might be pregnant), then you should not participate in the study." (*Note*. The reviewers of this proposal are directed to the informed consent for a complete description of the study's methodology).

4. As mentioned in previous items, volunteers will be completely informed of the risks. In addition, the informed consent will instruct volunteers to not participate in the study if they "have been diagnosed with heart disease, diabetes, and chronic obstructive pulmonary disease (including severe asthma), have recently experienced a musculoskeletal injury, have been told by a health care provider to not exercise, or are pregnant (or think they might be pregnant). The health history form is explicit and requires that volunteers answer whether they have been told by a doctor that they have a heart problem, suffer chest pain, experience dizziness or faintness, have a history of joint or bone problems, take or have been advised to take medication for heart or blood pressure conditions or have any other physical condition that might impair safety.

As mention in item #3, at each testing, we will advise participants that if they experience a very fast heart rate, very slow heart rate, a pounding sensation in their chest, chest pain, pain in their arms, dizziness, or difficulty breathing, they are to stop exercising and notify a test administrator immediately. The test administrator will call 911 if needed.

In order to minimize potential risk, each participant is able withdraw from this study at anytime without any consequences to his/her course grade. In addition to having self-control over termination, other safety measures will be implemented: 1) the aerobics instructor (i.e., the primary investigator) is certified in CPR, and 2) the testing room is in close proximity to the athletic training offices.

All participants' personal information will be kept confidential. Data will be kept in a locked cabinet in Dr. Lisa Lloyd's office. Dr. Lloyd, Dr. Walker (statistician), and Jennifer Ahrens (thesis student) will use this information for research, but the participant's name will not be given out in any reports.

5. Participation in the study will provide the students with knowledge about the testing procedures and about how to carry out a scientific experiment. The results of this experiment will provide each student with the knowledge regarding the effects of caffeine on the monitoring of

their own intensity during a bout of aerobic exercise as well as there own current level of fitness.

6. As previously stated, the risks associated with this proposal are minimal, while the potential benefits are great. In short, the risk/benefit ratio greatly favors the potential benefits for not only the scientific community, but also to the participants, themselves, and anyone who consumes caffeine and then exercises. The investigators envision, as a result of this research, a better understanding of the effects of caffeine on one's ability to accurately monitor intensity during exercise, in particular, during aerobic dance bench stepping.
7. This study will be conducted in the Human Performance Laboratory. It has been approved by Dr. Lloyd, who is the Director of the Human Performance Laboratory and the Chair of Jennifer Ahrens (the primary investigator of this study) thesis committee.
8. This project is being conducted for my thesis. My Committee Chair is Dr. Lisa Lloyd, professor in the Department of Health, Physical Education, and Recreation Department. She can be reached at (512) 245-8358. Other committee members include: Dr. John Walker, The Department of Health, Physical Education, and Recreation, and Sylvia Crixell, the Department of Nutrition and Foods.

9. This investigation has the approval of members on my thesis committee: Drs. Lloyd, Walker, and Crixell.

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VITA

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