



*Original Research*

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## **Effect of Caffeine on near Maximal Blood Pressure and Blood Pressure Recovery in Physically-Active, College-Aged Females**

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### ABSTRACT

*International Journal of Exercise Science 10(2): 266-273, 2017* The purpose of this study is to determine how caffeine affects exercise blood pressure (BP) and active and passive recovery BP after vigorous intensity exercise in physically active college-aged females. Fifteen physically active, ACSM stratified low-risk females (age (y):  $23.53 \pm 4.07$ , weight (kg):  $60.34 \pm 3.67$ , height (cm):  $165.14 \pm 7.20$ , BMI (kg/m<sup>2</sup>):  $22.18 \pm 1.55$ ) participated in two Bruce protocol exercise tests. Before each test participants consumed 1) a placebo or 2)  $3.3 \text{ mg} \cdot \text{kg}^{-1}$  of caffeine at least one hour before exercise in a counterbalanced double-blinded fashion. After reaching 85 % of their age-predicted maximum heart rate, BP was taken and participants began an active (i.e. walking) recovery phase for 6 minutes followed by a passive (i.e. sitting) recovery phase. BP was assessed every two minutes in each phase. Recovery times were assessed until active and passive BP equaled 20 mmHg and 10 mmHg above resting, respectively. Participants completed each test 1-2 weeks apart. Maximal systolic and diastolic blood pressures were not significantly different between the two trials. Active recovery, passive recovery, and total recovery times were all significantly longer during the caffeine trial than the placebo trial. Furthermore, the time to reach age-predicted maximum heart rate was significantly shorter in the placebo trial than the caffeine trial. While caffeine consumption did not significantly affect maximal blood pressure, it did affect active and passive recovery time following vigorous intensity exercise in physically active females. Exercise endurance also improved after consuming caffeine in this population.

**KEY WORDS:** Cardiorespiratory fitness, recreational athlete, exercise test, ergogenic aid

### INTRODUCTION

Caffeine is one of the most commonly consumed drugs throughout the world and has minimal health risks (10). Since caffeine can be found in many foods and drinks, its effect on the body and cardiovascular system should not be overlooked. Caffeine has been shown to improve mood, enhance psychomotor performance, enhance cognitive performance in healthy

volunteers (24) and has diverse physiological effects including central nervous system stimulation (14). Caffeine intake has consistently been shown to increase systolic blood pressure through its effects on systemic vascular resistance (2). Caffeine is also seen as an adenosine antagonist where it stimulates the central nervous system (16) by preventing the repressor effects on arousal (23) and neurotransmitter release (18). Caffeine is an antagonist competitor for these adenosine receptors, acting on these receptors in many areas, including whole body peripheral circulation and at the brain cortex (5). Evidence has shown that caffeine has a broad scope of pharmacologic effects and has been positively associated with cardiac stimulation, arrhythmias, and coronary heart disease (24).

In 2004 the World Anti-Doping Agency removed caffeine from the banned substances list (31) and the National Collegiate Athletic Association set a high urinary level of 15  $\mu\text{g}/\text{mL}$  to be tested positive for caffeine (17). This loosening of regulations increases the need for deeper investigation on the effects of caffeine during exercise and sport performance. As athletes commonly use caffeine as an ergogenic aid (10), it is important to know caffeine's effect on blood pressure during and after exercise.

At rest, caffeine has been shown to have a stimulatory effect on systolic blood pressure and diastolic blood pressure (8). However, results from resting measurements are not applicable to someone who is exercising. Dosing caffeine relative to body weight is common practice in exercise science research. To induce improvements in exercise performance, a dose of 3-6  $\text{mg}\cdot\text{kg}^{-1}$  taken prior to the performance seems to be sufficient (9). An article by Sung assessed the effects of 3.3  $\text{mg}\cdot\text{kg}^{-1}$  of caffeine on blood pressure during exercise in normotensive healthy young men. Sung found that during maximal exercise 44% of their participants had a significant increase in systolic and/or diastolic blood pressure during the caffeine trial when compared to the placebo trial (27). This is more than twice the number showing such a response to exercise alone (27). This suggests that caffeine has an effect on blood pressure during exercise in men, suggesting an increased sympathetic response. However, there has been a lack of research on the effects of caffeine on women during exercise and sport performance (13).

The influence of caffeine on blood pressure and blood pressure recovery in women has not been well documented. The purpose of this study is to determine how caffeine affects maximal blood pressure and blood pressure recovery after maximal exercise in physically active college-aged females. It is hypothesized that caffeine will raise the participant's maximal blood pressure and extend the period of time it takes for blood pressure to recover from maximal work.

## **METHODS**

### *Participants*

In this study, data was collected from 15 physically active college age females. All participants signed a written informed consent form approved by and Institutional Review Board and had

descriptive variables (i.e. age, height, weight, medical history, caffeine usage, and a list of medications they were currently taking) recorded. The participants had to be classified as low risk individuals by the American College of Sports Medicine's (ACSM) guidelines. To be considered low risk by the ACSM, participants had less than two risk factors for cardiovascular disease and no signs, symptoms, or diagnoses of pulmonary, cardiac, or metabolic diseases (19). Furthermore, individuals that had no risk factors, had a body mass index  $<25 \text{ kg/m}^2$ , and were younger than 45 years old are considered to have normal fasting glucose levels according to ACSM and to be at low risk without the need of a blood draw. Finally, all participants completed a survey determining how much physical activity they complete according to the ACSM's criteria.

### *Protocol*

This study was a counterbalanced double-blind study. Participants took part in two maximal exercise tests after consuming either 1) a placebo or 2) a dosage of  $3.3 \text{ mg}\cdot\text{kg}^{-1}$  of body weight of caffeine. The caffeine was in powder form and was dissolved in 10 oz. of unsweetened cranberry juice to hide the bitter taste of the caffeine powder. The placebo drink was 10 oz. of the unsweetened cranberry juice. This dosage was used in the Sung study and showed significant results in healthy normotensive men (27).

In the 72 hours leading up to each test, participants were asked to refrain from consuming food and drinks containing caffeine. They were provided a list of common foods and drinks containing caffeine. Rongen et al. found that 72 hours was shown to avoid the effects of caffeine tolerance (25). In the 1-2 weeks between trials, participant caffeine consumption was not controlled, except the 72-hour period before testing. During each trial participants were asked to arrive one hour before the test began. Their resting blood pressure (i.e. sitting position with feet flat on the floor and back supported) was taken just prior to consuming the 10 oz. placebo or caffeine beverage. The exercise test began one hour after participants consumed the beverage. The one hour wait time was the same whether the participant drank the placebo or the caffeine beverage. After the hour wait participants performed a maximal treadmill exercise test using the Bruce protocol to 85% of their age-predicted heart rate max using the Gellish equation (19).

Each participant completed the two maximal treadmill exercise tests using the Bruce Protocol. During each test the participant's rating of perceived exertion (RPE) and heart rate were recorded during the last 15 seconds of each minute and their blood pressure was assessed during the last minute of each stage. Heart rate was monitored continuously to determine when the participant was at 85% of their age predicted maximum heart rate. When this was reached, the exercising portion of the test was completed. Blood pressure was immediately taken post-exercise and every 2 minutes during the active recovery phase at 2.0 mph and 0% grade until the following two criteria were met: 1) blood pressure was within 20 mmHg of their resting values and 2) 6 minutes had elapsed post-exercise. After the 6-minute period, participants began the passive recovery phase by sitting down until their blood pressure was within 10 mmHg of their resting blood pressure. The amount of time it took participants to

recover from near maximal exercise was recorded in minutes, as well as the amount of time it took participants to reach 85% of their age predicted maximum heart rate. Participants came back 1-2 weeks later to perform the second test.

### Statistical Analysis

A repeated measures ANOVA was used to assess if maximal and recovery systolic blood pressures and RPEs, were significantly altered following caffeine use. The amount of time it took to reach 85% maximal heart rate and exercise recovery was also assessed in minutes using a repeated measures ANOVA. The statistical software used was SPSS (IBM, Armonk, New York). The level of significance was set at  $p < 0.05$ .

## RESULTS

Measured values of descriptive characteristics of participants are presented in Table 1. In Table 2, exercise test characteristics of participants are presented. The participant's maximal systolic blood pressure (SBP) and diastolic blood pressure (DBP) were not significantly different between the caffeine and placebo trials. However, in the caffeine trial 60% of participants had a higher SBP and 40% had a higher DBP when compared to the placebo trial. The caffeine trial had significantly longer active recovery ( $F = 12.923$ ,  $p = 0.003$ ,  $\eta^2 = 0.48$ ), passive recovery ( $F = 6.167$ ,  $p = 0.026$ ,  $\eta^2 = 0.306$ ), and total recovery periods ( $F = 16.205$ ,  $p = 0.001$ ,  $\eta^2 = 0.537$ ) than the placebo trial. The time it took participants to reach their age-predicted maximum heart rate was significantly longer in the caffeine trial than the placebo trial ( $F = 7.445$ ,  $p = 0.017$ ,  $\eta^2 = 0.364$ ). RPE was not significantly different between the two trials.

**Table 1.** Participant Characteristics (n=15).

	Mean $\pm$ SD
Age (y)	23.53 $\pm$ 4.07
Height (cm)	165.14 $\pm$ 7.20
Weight (kg)	60.34 $\pm$ 3.67
BMI (kg/m <sup>2</sup> )	22.18 $\pm$ 1.55
Activity (hrs/wk)	3.77 $\pm$ 1.18
Activity (days/wk)	3.53 $\pm$ 1.06

Data are presented as mean  $\pm$  SD.

**Table 2.** Exercise Test Characteristics. (n=15).

	0mg Caffeine	3.3mg Caffeine
Maximal Systolic Blood Pressure (mmHg)	156.13 $\pm$ 21.41	161.93 $\pm$ 14.18
Maximal Diastolic Blood Pressure (mmHg)	71.87 $\pm$ 8.16	71.87 $\pm$ 8.53
Active Recovery (min)	3.87 $\pm$ 1.77	5.47 $\pm$ 2.07*
Passive Recovery (min)	1.47 $\pm$ 0.83	2.47 $\pm$ 1.30*
Total Recovery (min)	5.33 $\pm$ 2.06	7.93 $\pm$ 2.71*
Time to 85% HR (min)	7.20 $\pm$ 1.47	7.40 $\pm$ 1.12*
RPE	13.33 $\pm$ 1.88	13.13 $\pm$ 1.73

Data are presented as mean  $\pm$  SD. \*Caffeine trial and placebo trial significantly different at p value  $< 0.05$ .

## DISCUSSION

Determining the effects of caffeine intake on near maximal blood pressure and blood pressure recovery would help provide information for female athletes, researchers, and practitioners to better understand how caffeine affects blood pressure. This study examined caffeine's hemodynamic influences during exercise in physically active, college-aged females that were ACSM classified as low risk. While caffeine use did not increase systolic (SBP) or diastolic blood pressure (DBP) at near maximal exercise, the total recovery time from near maximal exercise was, on average, 2.6 minutes longer in the caffeine trial.

This pattern of results is in contrast with an article by Sung (27). Sung used a population of normotensive healthy young men for his study. The study reported a significant increase in SBP and DBP ( $p < 0.02$ ) during maximal exercise trial with caffeine consumption compared to a non-caffeine trial (27). Current results indicate that caffeine ingestion prior to near maximal exercise had no significant effect on near maximal SBP and DBP ( $p < 0.05$ ). Consequently, the hypothesis that caffeine would increase SBP and DBP at near maximal exercise was not supported. However, the study by Sung ran a maximum exercise test to exhaustion. Two different studies also found non-significant differences between SBP and DBP after exercise following caffeine consumption. Costa et al. used a submaximal exercise test on a population of normotensive active men (6). Daniels et al. used a submaximal cycle ergometry exercise session on a population of male and female cyclists (7). These results suggest that caffeine consumption does not affect submaximal exercise blood pressures.

The effects of caffeine on systolic blood pressure recovery were shown to be significantly longer during active, passive, and total recovery time compared to the placebo trial, based on the current results. Therefore, the hypothesis that caffeine would increase recovery time was supported. Souza et al. found similar results in a resistance training study assessing the effects of caffeine on hemodynamics after a resistance training session. They also found that SBP and DBP were significantly elevated for nine hours post-exercise (26).

Current results also indicate that participants took longer to reach 85% of their age predicted maximum heart rate in the caffeine trial. A systematic review by the University of Connecticut found that across 21 research studies, caffeine improved sport-specific endurance performance ranging from -0.3% to 17.3% improvements across studies (9). The present study showed a 2.7% increase in aerobic endurance. Furthermore, the results from Piha also found heart rate responses were lower under the influence of caffeine in ten healthy participants (20). The Piha study monitored heart rate responses following standing up and after an isometric handgrip test (20). Further research is needed in this area to determine whether caffeine lowers heart rate responses at near maximal and maximal exercise.

Current results showed that RPE was not significantly different between the caffeine trial and placebo trial. However, several other studies found that there was a significant reduction in RPE after caffeine consumption (11, 12, 29). These studies each tested one of the different

aspects of health-related fitness (i.e. muscular strength, muscular endurance, cardiovascular endurance, flexibility, body composition). However, there are studies that have found that caffeine does not significantly reduce RPE (3, 28). One study in particular found that RPE was not significantly altered after caffeine ingestion during intense exercise in active women (1).

A source of variation in the effects of caffeine across these studies may be the tolerance level of habitual users. It has been found that caffeine can show significant effects on cognition and hemodynamics in habitual users after abstinence (15, 21, 22, 30). Our participants abstained from caffeine for 72 hours before each exercise trial (25).

Results from this study were limited by the near maximal nature of the exercise test. A maximal test to exhaustion may have shown differences in SBP, DBP, and RPE. Additionally, research has shown that habitual caffeine users who abstain from caffeine for at least seven days will optimize the ergogenic effect (9). Seven days of caffeine abstinence would have been optimal, but we still had significant results with the 72-hour washout period that was deemed sufficient in previous research (25). More research is needed on caffeine's effect on active women. Further research is also needed to determine the effects of caffeine on maximal blood pressure and blood pressure recovery in a sedentary female population and to determine the effects of caffeine on heart rate responses at near maximal exercise.

In summary, current results suggest that caffeine significantly increases active and passive recovery time following near maximal exercise in active females. The responses of recovery time to caffeine may have clinical and practical significance to those who use caffeine before exercise. The current study also provides evidence that caffeine has an ergogenic effect on endurance and near maximal heart rate responses. Overall, this study shows that a caffeine dose of 3.3 mg·kg<sup>-1</sup> has the potential to lengthen the amount of time it takes to reach near maximal heart rate and also increases the amount of time it takes for blood pressure to recover from near maximal exercise.

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