Effects of caffeine and coffee on females.

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Abstract

The effects of caffeine on the human body are variable. Possible effects on the female body include changes in blood pressure and heart rate. The present study examined the female response to coffee and caffeine at rest and exercise. Twenty-four healthy, college age women (age: 20.2[+ or -]1.47, height: 166.65[+ or -]7.62, body mass: 62.99[+ or -] 10.80) volunteered to participate in this research study. On day one, two, and three subjects had their blood pressure and heart rate recorded at rest and exercise (treadmill: 4.85 km/hr, 10% grade) after ingestion of no substance (day one), coffee (day two), and caffeine (day three). No significant differences were noticed in the heart rate response for the different treatments. Significant changes were noticed in the systolic blood pressure (143.79 [+ or -]17.36 with coffee ingestion vs. 135.96 [+ or -]14.22, and 132.79 [+ or -]16.84 with no substance and caffeine respectively) and diastolic blood pressure (75.96 [+ or -]14.98 with coffee ingestion vs. 69.50 [+ or -]10.72 and 68.58 [+ or -]11.12 with no substance, and caffeine respectively) among the three treatments. Coffee, but not caffeine ingestion, seemed to increase systolic and diastolic blood pressure during exercise. The present study also observed a 6.42% difference in the systolic blood pressure double products at rest and exercise.

Comparative Analysis of the Effects of Caffeine and Coffee on the Blood Pressure and Heart Rate Response during Rest and Exercise among College Aged Women

Caffeine is a very widely used substance and one ingredient found in coffee, carbonated beverages, energy drinks, and foods. Caffeine effects on the human body are variable, depending on the amount of caffeine ingested. The overall response of individuals to the substance differs (Papaioannou & Vlachopolous, 2006). Usually, one tends to see an increase in blood pressure (BP) and heart rate (HR) with the ingestion of coffee. The hemodynamic effects of chronic coffee and caffeine consumption have not been sufficiently studied. The possible mechanisms of the cardiovascular effects of caffeine include the blocking of adenosine receptors and the inhibition of phosphodiesterases (Nurminen & Nuttynen, 1999). Several studies reported elevation in BP as a direct consequence of caffeine ingestion (Jeong, 1990; Papaioannou et al., 2006; Nurminen et al., 1999). Also, the research of Danniels, Mole, Shaftath, and Stebbins (1998) on the effects of caffeine on BP, HR, and forearm blood flow during dynamic leg exercise, confirms that caffeine may alter the cardiovascular response during exercise.

Caffeine in its role as an ingredient in coffee has been blamed for several negative effects on the body, mainly an increase in BP, which is significant for people with hypertension. On the one hand, caffeine is believed to boost an athlete's performance and has consequently been reported in the 2004 Monitoring Program by the World Anti-Doping Agency (WADA) in order to detect patterns of misuse in sports (2004). Currently, caffeine is no longer in the above-mentioned list. On the other hand, caffeine increases sub-maximal exercise performance in healthy young subjects (Notarius & Morris, 2006). Unfortunately, its effects on exercise tolerance in heart failure (HF) have not been characterized. In general, caffeine allows HF patients to exercise longer at peak effort (Notarius et al., 2006). Caffeine is also reported to have a positive effect on reducing leg muscle pain during exercise among females, but this effect does not appear to be dose-dependent between 5 and 10 mg-kg body weight caffeine (Motl & O'connor, 2006).

Other researchers (Greenberg, 2006; Boozer, 2006) focusing their efforts on the effect of coffee on the human body, confirm that caffeine in coffee might be the reason for elevation in BP Such findings provide evidence that cardiovascular patients may be at a higher risk than non-symptomatic patients. On the contrary, the research of Sudano & Binggeli (2005) on the cardiovascular effects of coffee suggests that coffee intake not only does not place people at a higher risk, but can have positive results on the overall cardiovascular health.

Unfortunately, very little information on this topic has been reported on women. One of the few studies completed suggests that no relationship between caffeine and hypertension was present (Winkelmayer & Stampfer, 2005). Also, there was no difference between the flight-or-fight response in both women and men (Farag & Wincent, 2006). Ahrens & Lloyd (2007) suggest that in women caffeine had no effect on the rating of perceived exertion, HR, or respiratory exchange ratio. Interestingly, they also found that a 6-mg x kg (-1), but not a 3-mg x kg (-1) dose of caffeine, increased VO2 in the female subjects.

With a few exceptions (Yeragani & Krishnen, 2005) HR is not significantly influenced by substances such as coffee or caffeine. Ahrens et al. (2007) revealed that neither dose of caffeine had any effect on the VO2, VCO2, minute ventilation, or HR during aerobic-dance bench stepping.

In general, the public seems to be confused and uses the terms coffee and caffeine interchangeably as main contributors to similar effects on the human body. People have been advised by physicians to maintain a balanced diet and practice moderation with substances such as caffeine. Accordingly, strategies for encouraging reduced dietary levels of caffeine deserve serious consideration (James, 2004).

Therefore, the purpose of this study was to differentiate the effects of caffeine alone and caffeine in coffee. The research question was based on the connection between the effects of pure caffeine and coffee, and consequently, if other ingredients in coffee are to be blamed for the reported, but still unclear negative effects of caffeine on BP Moreover, this study analyzed the female response to coffee and caffeine at rest and during exercise.

Method

Subjects

Twenty-four healthy college age women (age: 20.2 [+ or -]1.47, height: 166.65 [+ or -]7.62 m, body mass: 62.99[+ or -]10.80 kg) volunteered to participate in this research study. All subjects were full-time, residential students at a rural liberal arts college. Awritten informed consent was signed by the subjects after being informed about all risks, discomforts, and benefits of this study. Undergraduate Research and Creative Projects Committee (URCPC) approval was obtained for this study and procedures were in accordance with the Helsinki Declaration of 1975.

Subjects were screened by telephone interview and in person to exclude those that had allergies, any known negative effects towards caffeine, who were pregnant, breast-feeding, hypertensive, or currently ill. Subjects were required to refrain from Midol[R], diet pills, or any other caffeine or methylxanthine containing substances (chocolate, coffee, Mountain Dew, Coca Cola, Pepsi, or other power exercise beverages) for at least 24 hours before each testing session. Subjects were also asked not to change any major aspects of their lifestyle immediately before or during the course of the study.

Experimental Design

The study design required female subjects to visit the testing site on three consecutive days. Participants were required to attend all three of the testing days. The subjects were tested at approximately the same time of day so error in BP variability to hour of the day was reduced. The total time for the testing of all subjects did not exceed three weeks.

On day one, subjects visited the testing site and signed an informed consent form after having all their questions answered concerning the study. Resting baseline blood pressure and heart rate were taken three times over a period of 45 minutes. Participants were then required to walk on a treadmill for 6 minutes in order to reach a steady HR (treadmill speed: 4.85 km/ hr; treadmill grade: 10%, equivalent of 7.4 Mets). Their baseline exercise BP and HR was recorded. On day two, subjects visited the testing site for 65 minutes. They drank two 100mg cups of Folgers [R] instant coffee (containing a total of 200 mg caffeine). Their BP and HR were taken after 20 minutes of rest. Subjects' BP and HR were also recorded another three times over the next 30 minute period (in 10 minute increments). Participants were then required to walk on a treadmill with the same parameters as day one (treadmill speed: 4.85 km/hr; treadmill grade: 10%). BP and HR responses were monitored and recorded during the course of exercise. On day three, the procedures of day two were repeated. The only difference was that a 200 mg caffeine pill (Equate [R]-Stay Awake) was used in the place of two 100 mg cups of instant coffee. Factors such as time of day, monitoring of BP and HR, and equal amounts of caffeine on day two and three were strictly observed.

Blood Pressure and Heart Rate Apparatus

Subject's BP and HR were recorded throughout the study using an auto-inflate digital BP monitor with a D-ring arm cuff (Omron BEM-71 1AC). The monitor was rated number one by the top independent United States product testing laboratory and had been found accurate in validation studies using the protocols of the British Hypertension Society in 2006. The cuff was applied to the left arm, above the elbow and directly to the skin. Inflation and deflation of the arm cuff was automatically monitored through the device's Intellisense[TM] technology.

Measurement

Measurements were recorded at increments of 10 minutes during rest and at the sixth minute during exercise. BP and HR were recorded at regular intervals for each subject. Substance ingestion

On day two, subjects received two 100 mg cups of Folgers [R] instant coffee containing a total of 200 mg of caffeine. Subjects were allowed to drink the fluid as rapidly or slowly as they wished. On day three, participants were asked to take a 200 mg caffeine pill (Equate [R]-Stay Awake) with 200 mg of water. Subjects were asked to report any signs of gastrointestinal discomfort before, during or after the ingestion of the different substances. Statistical analyses

A repeated-measures Analysis of ANOVA (treatments [3] x time [3]) was used to determine whether there were statistical differences in the BP and HR data collected on days one through three. StatView 5.0 for Windows was used for the analyses.

Results

Significant changes ($p<0.05$) were noticed as presented in Tables 1, 2, and 3. Significant differences for the intensity and treatments were also noted among the responses of the subjects. Heart Rate

There was no significant change in the HR response for the treatments among the females tested. As presented in Table 1, the mean HR and standard deviations at rest with no substance consumption, with coffee, and with caffeine are respectively 69.00 [+ or -]10.65, 68.46 [+ or -]12.37, 64.63 [+ or -] 10.59. At exercise, there was significant increase in the HR as expected. The HR at exercise with no substance consumed, with coffee and caffeine was respectively 113.88 [+ or -] 22.35, 114.04 [+ or -] 20.37, 109.46 [+ or -] 26.47. Systolic Blood Pressure (SBP)

There were significant differences ($p<0.05$) noticed among the different treatments (no substance, coffee, and caffeine). A Fisher's PSLD Post-Hoc test confirmed the significant differences between no substance, coffee, and coffee-caffeine. As expected, there was also a difference in the SBP with increased intensity from rest to exercise. Table 1 depicts and compares the data between the two intensities and the three treatments. The SBP at rest during the three treatments was respectively 109.00 [+ or -]10.24, 110.54 [+ or -] 10.86, 107.38 [+ or -]9.38. At exercise, the SBP was 135.96 [+ or -]14.22, 143.79 [+ or -] 17.36, 132.79 [+ or -]16.84. The difference in the double products (HR* SBP) for no substance and coffee was found to be 1047 or a 6.42% increase.

Diastolic Blood Pressure (DBP)

No significant differences in the DBP response were observed between the two intensities. A significant difference was found when results from the treatments were analyzed. Table 3 summarizes the findings. The differences between treatments with no substance, with coffee, and with caffeine were respectively 66.17 [+ or -] 10.61, 72.50 [+ or -] 11.76, 65.67 [+ or -] 7.21. The DBP response for the same treatments with exercise was as follows: 69.50 [+ or -]10.72, 75.96 [+ or -] 14.98, 68.58 [+ or -] 11.12.

The typical hemodynamic response to exercise is 5-10 mmHg/ Mets increase in SBP (Taylor & Beller, 1998). As observed the systolic mmHg per Met with no substance, with coffee, and caffeine ingestion were respectively 4.21, 5.20, and 3.97. Also, the diastolic mmHg per Met with no substance, with coffee, and caffeine were noticed to be 0.52, 0.54, and 0.45. A summary of the mmHg/Met equivalents is presented in Figure 1.

[FIGURE 1 OMITTED]

Discussion

The results from the present study demonstrated that there were no significant changes in the HR for the different treatments with no substance, coffee and caffeine at rest and during exercise among the females tested. The findings are in agreement with previous reports on the relationship between coffee and caffeine on the HR response (Yang & Tiselius, 2007; Ahrens & Crixell, 2007; Crowe & Leicht, 2006; Daniels & Mole, 1998). As expected, HR increased only with increase in intensity from rest to exercise.

Yeragani, Krishnan, Engels, and Gretebeck (2005), on the other hand, reported that there was a significant increase in HR and a decrease in HR variability after exercise during both placebo and caffeine ingestion. This research group also found that pre-exercise caffeine condition was associated with a significant increase of HR variability with extremely high frequency range (0.15-0.5 Hz). The final conclusion was that the caffeine might have different effects on the heart rate at exercise and rest. This might also have an application for patients with cardiac illnesses who use caffeinated beverages.

Some of the studies on animals suggested that heart rate response to caffeine might be dose-dependent. Ilbach, Siller, and Stalhandske (2007) concluded that caffeine was found to induce, to various degrees, a dose-dependent early increase in spontaneous physical activity, HR, SBP, and DBP. They also found that the highest dose of caffeine (45mg/kg b.w.) induced a biphasic response, with an early and pronounced increase in body temperature, spontaneous physical activity, SBP&DBP. Caffeine seemed to play a minor role in small doses, confirmed in the present study, but when increased to 75mg kg (-1), it lessened the responses. Caffeine was reported to influence the adenosine receptor which is involved in the regulation of HR, body temperature, and locomotor activity. Also, intermediate doses of caffeine (30mg kg (-1)) appeared to increase or decrease the HR in rats depending on sex and genotype (Yang et al., 2007). Significant differences ($p<0.5$) were noticed in the SBP response at rest and exercise during the three treatments (no substance, coffee, and caffeine). There was a noticeably larger increase in the SBP with the ingestion of coffee than with no substance or caffeine. This finding does not support the conclusions of Lancaster, Muir, and Silagy (1994) who found that coffee had no significant effects on total or high-density lipoprotein (HDL) cholesterol or BP in the population of the United Kingdom. They concluded that the coffee drank in the United Kingdom did not present any significant risks of cardiovascular disease of any type. Burr, Gallacher, Butland, Bolton, and Downs (1989) did not find any significant changes in the DBP response due to coffee among the British population. They also supported the previous findings that coffee was not associated with heart disease in Britain.

Other researchers, however, found that BP increased with the ingestion of caffeine (Engls & Wirth, 1999; Daniels et al., 1998; Winkelmayer et al., 2005; James et al., 2004; Hartley &

Lovallo, 2004; Robertson & Frolich, 1978), which does not support the present study. Most of these research studies used a mg/per body weight equivalent of caffeine, but did not specify what source of caffeine they implemented. They also stated that the particular amount of caffeine was equivalent to certain amounts of coffee, but failed to account for the many different ingredients in the various brands of coffee. Those ingredients, either alone or grouped together, might cause a certain BP response.

Other variable responses were noticed in the research results of Robertson et al. (1978) who observed that after caffeine ingestion mean BP rose 14/1 OmmHg one hour after the ingestion of the substance. No such result was observed with the ingestion of pure caffeine in the present study. Furthermore, there was also a fall and then a rise in the HR. Also, Lovallo et al. (2004) concluded that women responded to caffeine with increases in stroke volume ($p < 0.001$) and cardiac output ($p < 0.001$), with no difference in vascular resistance from women taking placebo. In this same study men and women showed similar BP responses to caffeine, but the BP responses might have been due to different homodynamic mechanisms. Women who consumed a dietary dose of caffeine showed an increase in cardiac output; whereas, men showed increased vascular resistance. The DBP also seems to be influenced by coffee more than caffeine. Even though there was a slight difference, there was no statistically significant difference found.

The literature seems to be contradicting on the topic of caffeine and its effects on BP. Even though there is more research done on men than on women, there does not seem to be a single study that fully explains the cause of increased BE A major study was conducted by Winkelmeyer et al. (2005) on the habitual caffeine intake and the risk of hypertension in women. They concluded that no linear association between caffeine consumption and incident hypertension in women was found. It was suggested that sugary caffeinated beverages might be a cause for hypertension. The present study supports this conclusion in the sense that pure caffeine did not cause any significant increase in the SBP, while coffee did. HR was not influenced by coffee or caffeine. DBP did not significantly increase, either. Further research is needed to analyze the different ingredients in popular brands of coffee and examine their influence independently or in groups with other ingredients of coffee on females. Also, as suggested by Winkelmeyer et al. (2005), sweetened coffee (artificially or naturally) should be examined and results compared to coffee with no sweetener in it. Also, future research might analyze the effects of decaffeinated coffee on women at rest, moderate, and high intensity exercise. The present study also observed a 6.42% difference in the SBP double products at rest and exercise. Double product is an indirect index of cardiac oxygen consumption, and thus, the above percentage becomes significant and might hinder performance at lower intensities and even put the individual at a disadvantage or risk at high intensities.

[ILLUSTRATION OMITTED]

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Table 1
Heart Rate Response (mean beats per minutes [+ or -] SD).

	Heart Rate	
Intensity	w/ No Substance	w/ Coffee
Rest	69.00 [+ or -] 10.65	68.46 [+ or -] 12.37
Exercise	113.88 [+ or -] 22.35 ([dagger])	114.04 [+ or -] 20.37 ([dagger])

Intensity	w/ Caffeine
Rest	64.63 [+ or -] 10.59
Exercise	109.46 ([dagger]) 26.47 ([dagger])

([dagger]) p<0.05, for Intensity

Table 2
Systolic Blood Pressure Response (mean mmHg [+ or -] SD).

Intensity	Systolic Blood Pressure w/ No Substance	w/ Coffee
Rest	109.00 [+ or -] 10.24	110.54 [+ or -] 10.86
Exercise	135.96 [+ or -] 14.22 ([dagger]) ([double dagger])	143.79 [+ or -] 17.36 ([dagger]) ([double dagger])

Intensity	w/ Caffeine
Rest	107.38 [+ or -] 9.38
Exercise	132.79 [+ or -] 66.84 ([dagger]) ([double dagger])

([dagger]) $p<0.05$, for Intensity

([dagger]) ([double dagger]) $p<0.05$, for Treatments

Table 3
Diastolic Blood Pressure Response (mean mmHg [+ or -] SD).

Intensity	Heart Rate w/ No Substance	w/ Coffee
Rest	66.17 [+ or -] 10.61	72.50 [+ or -] 11.76
Exercise	69.50 [+ or -] 10.72 ([dagger])	75.96 [+ or -] 14.98 ([dagger])

Intensity	w/ Caffeine
Rest	65.67 [+ or -] 7.21
Exercise	68.58 [+ or -] 11.12 ([dagger])

([dagger]) $p<0.05$, for Treatments