



Effect of Caffeine on Cardiorespiratory Parameters in Sedentary, Healthy Young Male Adults

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Abstract

Background: In current days of highly competitive life, all of us are under pressure to perform better. Once we reach optimal level of performance according to genetic makeup, the subsequent increment in performance depends upon various ergogenic methods to enhance the energy delivery system. Of the various ergogenic methods available to achieve excellence, caffeine consumption is increasingly popular.

Aims and Objectives: The present study was undertaken to study the effect of caffeine (6mg/kg body weight) on cardiovascular & respiratory parameters after 5 minutes of stationary cycling on a bicycle ergometer, in sedentary young male adults of age 18-26 years.

Materials and Methods: The participants were made to complete a graded exercise protocol on a bicycle Ergometer in order to determine the power output required to elicit a THR, equating to 55% of individual age predicted maximum HR (220 - age). The following parameters were measured, Systolic BP (SBP) in mm Hg, Diastolic BP (DBP) in mm Hg, Mean Arterial Pressure (MAP) in mm Hg, Maximum heart rate in beats per minute (bpm), Target heart rate (THR) in beats per minute (bpm), Double product of HR & SBP, Respiratory rate (RR) per minute, Maximum volume of oxygen consumption by body in each minute during exercise (VO₂max) in ml/kg/min. At the end of 5 minutes (i.e. during recovery period), subjects pulse rate was measured at three different times: at the end of 1 minute, 3 minutes, 5 minutes after the exercise was over. In the second visit after 2 days of first session the same participants were given caffeine anhydrous powder in a dose of 6mg/kg of body weight, one hour prior to exercise session and after 5 minutes of exercise session, the above mentioned parameters were measured. All the mentioned parameters before and after caffeine consumption were compared using Paired t- test.

Results: There was statistically significant increase in systolic blood pressure, diastolic blood pressure, mean arterial pressure, target heart rate, double product of heart rate and systolic blood pressure, in respiratory rate, 1 minute post-exercise heart rate (PHR1), 3 minute post-exercise heart rate (PHR3), 5 minute post-exercise heart rate (PHR5) and significant decrease in VO₂max, after one hour of caffeine consumption with exercise in male and female participants.

Conclusion: The present study shows that caffeine (6mg/kg body weight) ingestion prior to a short term exercise has an ergogenic effect by making appropriate changes in above mentioned cardiovascular & respiratory parameters in a normal young adults of age 18-26 years.

Keywords-caffeine, submaximal exercise, cardiopulmonary parameters, VO₂max.

Introduction

Exercises are usually performed to improve cardiorespiratory & muscular endurance.¹ Submaximal testing is a popular & effective way of evaluating cardiorespiratory fitness (CRF) & is valuable in developing individualized exercise programmes,² as test administrators requires less training and exercise intensity is realistic for most participants. Cycle ergometer has an appealing mode of testing CRF as it allows the selection of precise work rates that can be expressed with appropriate units of power, and is usually well tolerated by individuals with orthopaedic and other physical limitation and also heart rate, blood pressure & electrographic data can be easily recorded during the test protocol. Once we reach optimal level of performance according to genetic makeup, the subsequent increment in performance depends upon various ergogenic methods to enhance the energy delivery system.³ An ergogenic aid by definition is a substance or device that enhances energy production, for use in competition or recovery⁴.

Of the various ergogenic methods available to achieve excellence, caffeine consumption has become increasingly popular.⁴ Caffeine is consumed by all of us & it is one of the most widely used substances in the world. Every morning millions of people wake up to that morning cup of coffee that enables them to start their day.⁵ Many studies have reported an enhancement of prolonged submaximal exercise after caffeine ingestion.⁶ Caffeine affects almost every system in the body with the most effect on central nervous system.⁵ Caffeine acts as a central stimulant & has effects on cognitive & psychomotor functioning, particularly during mental & physical fatigue and by enhancing alertness & vigilance, it dampens pain perception, delays sleep.^{6, 7, 8}

Aims and Objectives

1. To study the changes in the following (a) cardiovascular & (b) respiratory parameters after 5 minutes of stationary cycling on bicycle ergometer, at a standardized power

output in sedentary young male adults of age 18-26 years.

Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Mean Arterial Pressure (MAP), Target Heart Rate (THR), Double Product of HR & SBP, 1minute, 3minute, 5minute post-exercise heart rate, Respiratory Rate (RR), Maximum Volume of oxygen consumption in each minute (VO₂max).

2. To study the effect of caffeine (6mg/kg body weight) on above mentioned cardiovascular & respiratory parameters after 5 minutes of stationary cycling at a standardized power output in the same sedentary young male adults of age 18-26 years.
3. Comparison of above obtained results & draw conclusions.

Materials and Methods

The study was conducted in the Department of Physiology in a tertiary hospital in city of Mumbai after approval by the ethics committee.

Study Population

75 normal, healthy, working male individuals of 18-26 years of age without peptic ulcer disease, bronchial asthma, tuberculosis or any major medical or surgical illness were randomly selected from a medical college in Mumbai.

Criteria for Selection of Subjects

Inclusion Criteria

- Age between 18-26 years.
- Male subjects.
- Healthy, working.
- Non-regular caffeine users (less than 2cups of coffee or equivalent /week).
- Non – athletes.

Exclusion Criteria

- Age less than 18 or more than 26 years.
- Obese individuals.
- Smokers.
- Alcoholics.

- Regular caffeine users (ingesting ≥ 300 mg caffeine / day).
- Performing more than 20 minutes of exercise on 3 or more / week.
- History of trauma.
- History of previous chronic disease.

Their nature of work in the entire day was basically a sedentary type. The subjects were first explained about the procedure of the test. Both verbal and written consents of the subjects were taken in their language. Detailed history of the subjects was taken regarding their diet, food preferences, personal habits, drug use or medication followed by detailed systemic examination of cardiovascular, respiratory, abdomen & central nervous systems. They were divided into 2 groups. Control group (group A) comprised of 30 male adults. Study group (group B) consisted of 45 male participants. The participants were instructed to refrain from consuming caffeine for 48 hours prior to testing sessions as well as to avoid heavy exercise & alcohol for 24 hours prior & continue their routine. A list of food & beverages containing caffeine was provided to each participant in order to inform them of what products they should avoid. The control group was asked to exercise on the bicycle ergometer only during the first visit, they were not given caffeine for consumption. The study group were examined twice, once before caffeine consumption along with the control group and second time when they were given caffeine anhydrous powder in a dose of 6mg/kg of body weight during their second visit. The subjects, both control group and study group were called in the morning after having light breakfast and were made to sit comfortably on a chair in a well – lit & ventilated room at room temperature.

The following anthropometric parameters were studied

Age: was recorded from birthday by calendar to the nearest of year (<6months and >6 months)

Height: It was measured in cm, with the help of height measurement stadiometer. The subjects were asked to stand erect, bare foot with head straight,

feet together on the floor and the vertical distance from the ground to the vertex was measured.

Body Weight: It was measured in kg, by portable human weighing machine.

Body mass index: Was calculated by the formula $BMI = \text{Weight (in Kg)} / \text{Height (in m}^2\text{)}$

Body fat percentage is measured by Bicycle Ergometer.

The subjects were then asked to perform exercise on bicycle Ergometer (Upright Bike 9380u ,Most Perfectly Ent Co. Ltd., Taiwan). The first session was to familiarise the participants and required them to complete a graded exercise protocol on a bicycle Ergometer in order to determine the power output required to elicit a THR, equating to 55% of individual age predicted maximum HR ($220 - \text{age}$). Once the THR is attained, the participant was instructed to continue to cycle at the power output, that equated to this HR value for a duration of 5 minutes. The subject pedalled the bicycle at the rate of 60 revolutions/minute. The rate was constant throughout exercise session. After 5 minutes of exercise session, following parameters were measured.

Parameters Studied

Systolic BP (SBP) in mm Hg , Diastolic BP (DBP) in mm Hg, Mean Arterial Pressure (MAP) in mm Hg: $MAP = 1/3 (SBP - DBP) + DBP$, Maximum heart rate in beats per minute (bpm), Target heart rate (THR) in beats per minute (bpm), Double product of HR & SBP, also called Myocardial-Tension-Time (M.T.T.) which gives an index of myocardial oxygen consumption, Respiratory rate (RR) per minute, Maximum volume of oxygen consumption by body in each minute during exercise (VO_{2max}) in ml/kg/min by the following formula $VO_{2max} = 111.33 - (0.42 \times \text{THR in bpm})$. 10 At the end of 5 minutes (i.e. during recovery period), their pulse rate was measured at three different times : at the end of 1 minute , 3 minutes , 5 minutes after the exercise was over. There was no significant difference in the above mentioned cardiorespiratory parameters in the control group and study group.

After 2 days of first session only the study group (group B) participants were called for second time and were given caffeine anhydrous powder in a dose of 6mg/kg of body weight & instructed to ingest it with water in front of the investigator. After the rest period of 1hour, the exercise session as performed during the first visit was carried out. After 5 minutes of exercise session, above mentioned parameters were measured. The participants were not provided with any visual or verbal feedback regarding their work intensity.

Observations

Table 1 indicates the anthropometric parameters in control and participants. No significant difference was observed between the two groups for height, weight, BMI in both the age groups.

Table 2&3 illustrates mean values of cardiovascular parameters and Double product of heart rate and systolic blood pressure among study group male participants before and one hour after caffeine consumption with exercise. There is a statistical significant increase in all cardiovascular parameters, SBP (mm Hg), DBP (mm Hg), MAP (mm Hg), THR (bpm) and Double product of HR & SBP after caffeine consumption

Table 4 shows the comparison of mean values of Respiratory parameters before and one hour after caffeine consumption with exercise among study group male participants. There is a significant increase in RR and significant decrease in VO2max after caffeine consumption.

Table 5 illustrates the mean values of 1 minute post-exercise heart rate (PHR1), 3 minute post-exercise heart rate (PHR3), 5 minute post-exercise heart rate (PHR5) before and one hour after caffeine consumption with exercise among study group male participants. There is statistically significant increase in PHR1, PHR2, PHR3 in male participants after one hour of caffeine consumption with exercise.

Results

Table 1: Comparison of mean values of anthropometric parameters in male participants.

	Study group (N=45)		Control group (N=30)		Unpaired t- test	P value
	Mean	S.D.	Mean	S.D.		
Age (years)	19.58	1.733	20.58	3.872	1.213	0.232
Weight (kg)	63.42	10.464	54.00	13.545	2.467	0.018
Height (cm)	171.97	5.145	160.33	6.372	6.293	0.000
BMI (kg/m2)	21.35	3.172	20.95	5.078	0.320	0.750
Body Fat (%)	17.96	5.224	22.66	7.564	2.356	0.023

Table 2: Comparison of mean values of cardiovascular parameters before and one hour after caffeine consumption with exercise among study group male participants

Variable		Mean	S. D.	Paired t- test	P value
SBP (mm Hg)	Before	136.00	9.21	5.024	0.000
	After	150.00	9.61		
DBP (mm Hg)	Before	70.00	6.05	4.432	0.000
	After	80.00	5.74		
MAP (mm Hg)	Before	93.49	4.67	11.697	0.000
	After	102.87	3.93		
THR (bpm)	Before	128.52	9.06	15.428	0.000
	After	145.33	10.26		

Table 3: Comparison of mean values of Double product of heart rate and systolic blood pressure before and one hour after caffeine consumption with exercise among study group male participants

Variable		Mean	S. D.	Paired t- test	P value
Double product of HR & SBP	Before	17,766.85	2,119.39	5.012	0.000
	After	22,292.79	2,937.48		

Table 4: Comparison of mean values of Respiratory parameters before and one hour after caffeine consumption with exercise among study group male participants

Variable		Mean	S. D.	Paired t- test	P value
RR (/min)	Before	28.00	4.85	5.067	0.000
	After	34.00	4.11		
VO2max (ml/kg/min)	Before	57.35	3.81	15.424	0.000
	After	50.29	4.31		

Table 5: Comparison of mean values of 1 minute post-exercise heart rate (PHR1), 3 minute post-exercise heart rate (PHR3), 5 minute post-exercise heart rate (PHR5) before and one hour after caffeine consumption with exercise among study group male participants

Variable		Mean	S. D.	Paired t-test	P value
PHR 1 (bpm)	Before	118.33	11.31	8.320	0.000
	After	136.45	10.91		
Difference is significant					
PHR 3 (bpm)	Before	109.30	11.89	8.329	0.000
	After	125.00	10.66		
Difference is significant					
PHR 5 (bpm)	Before	102.52	9.11	7.650	0.000
	After	115.97	10.71		
Difference is significant					

Discussion

In the present study there was a statistically significant increase in all the cardiovascular parameters that is, Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Mean Arterial Pressure (MAP), Target Heart Rate (THR), Double Product of HR & SBP, after 5 minutes of stationary cycling on bicycle ergometer in normal young adults of age 18-26 years. Similar findings have been reported by various authors who studied the effect of caffeine on cardiopulmonary parameters.^{11, 12} On the contrary, Whitsett et al.¹³ found no differences in blood pressure and heart rate in either caffeine users or nonusers.

During a normal action potential the Ca^{+2} entry through the Ca^{+2} current (I_{Ca}) produces a small rise of $(Ca^{+2})_i$ which then activates further release of Ca^{+2} from SR i.e. ' Ca^{+2} -induced Ca^{+2} release.' By analogy with this, the addition of caffeine will increase SR Ca^{+2} permeability and allow Ca^{+2} ions to leave, thus increasing $(Ca^{+2})_i$. This will then (via Ca^{+2} -induced Ca^{+2} release) promote the release of more Ca^{+2} from SR. 14 here exists several mechanisms which explain pressor effects of caffeine. Caffeine and other methylxanthines have been known to exert positive inotropic effect on cardiac muscle. This effect has been explained by various theories which includes, an increase in cyclic adenosine monophosphate levels via inhibition of phosphodiesterase, caffeine induced release of calcium from the sarcoplasmic reticulum, antagonism of endogenous adenosine receptors and

thereby a progressive rise in vascular resistance and an increase in sympathetic activity.¹⁵

Double product of heart rate and systolic BP, also called as myocardial-tension-time index (M.T.T.I), gives an index of myocardial oxygen consumption.^{16,17,18} It is a relatively new and accepted index of left ventricular oxygen consumption and a substantial measure of the work load of the heart. There was statistically significant increase in double product in male participants after one hour of caffeine consumption with exercise, which may be due to increase in epinephrine and norepinephrine hormonal levels, increase in total peripheral resistance and/or an increase in stroke volume resulting in vasoconstriction and increased cardiac contractility.

Study of respiratory parameters revealed a statistically significant increase in respiratory rate (RR) after caffeine ingestion which may be due to stimulation of central nervous system (CNS) by methylxanthines which is known to augment the central inspiratory drive and increase chemoreceptor sensitivity to carbon dioxide. At the cellular level, xanthines block phosphodiesterases, therefore promoting cyclic adenosine monophosphate (AMP) accumulation. CNS is stimulated, with responses including (1) a regularized breathing pattern, (2) increased ventilatory drive, (3) increased chemoreceptor sensitivity to carbon dioxide.¹⁹

There was a significant decrease in VO_{2max} in all the participants after one hour of caffeine consumption with exercise. Donrawee et al.²⁰, Smile JS et. Al²¹, Nader et al²² in their studies have found significant increase in VO_{2max} after 1 hour of caffeine consumption with submaximal exercise testing. But Mousavi A et al. found caffeine has no significant effect on maximal oxygen consumption (VO_{2max}).²³ The O_2 delivery to the active muscles appears to be the limiting factor in muscle performance. VO_{2max} varies with the level of physical conditioning. The responses of the cardiovascular system to regular exercise is to increase its capacity to deliver O_2 to the active muscles and improve the ability of the muscle to use O_2 . Training progressively increases VO_{2max} ,

which reaches a plateau at the highest level of conditioning. Physical conditioning is also associated with greater extraction of O₂ from the blood by the muscles. With long-term training, capillary density in skeletal muscle increases. The number of mitochondria increases, as do the oxidative enzymes in mitochondria. In addition, levels of ATPase activity, myoglobin, and enzymes involved in lipid metabolism increase in response to physical conditioning.²⁴

Though various studies have revealed increase in VO₂ max after caffeine consumption which indicates caffeine to act as an ergogenic aid to enhance athletic performance, inhibit adenosine receptors and therefore increase skeletal muscle activity. However the decrease in VO₂max 1 hour after caffeine consumption with exercise in our study indicates that caffeine during short term exercise in untrained individuals doesn't have an ergogenic effect on VO₂ max. Thus caffeine does not appear to be ergogenic during short-term exercise. Training status may also play a role in eliciting exercise performance benefits associated with caffeine ingestion. To date, the majority of studies that reported significant improvement in exercise performance following caffeine ingestion involved well-trained athletes, whereas the effect of caffeine may be different in a non-athletic population. It can be speculated that adaptive physiological changes that occur in trained athletes may result in greater responsiveness or sensitivity to caffeine uptake and its consequent effects.²⁵

There was statistically significant increase in PHR1, PHR2, PHR 3 in male participants after one hour of caffeine consumption with exercise.

The increase in heart rate that accompanies exercise is considered to be due to the combination of parasympathetic withdrawal and sympathetic activation. The fall in heart rate immediately after exercise is considered to be a function of the reactivation of the parasympathetic nervous system. Recovery of heart rate immediately after exercise is a function of vagal reactivation.²⁶

Conclusion

The present study shows that caffeine (6mg / kg body weight) ingestion prior to a short term exercise has an ergogenic effect by making appropriate changes in mentioned cardiovascular & respiratory parameters in a normal young adults of age 18-26 years. The probable underlying mechanisms may be:

1. Caffeine exerts positive inotropic effect on cardiac muscle.
2. Caffeine causes increase in cyclic adenosine monophosphate levels via inhibition of phosphodiesterase.
3. Caffeine causes release of calcium from the sarcoplasmic reticulum via Ca⁺² -induced Ca⁺² release.
4. Antagonism of endogenous adenosine receptors.
5. Progressive rise in vascular resistance.
6. An increase in sympathetic activity causing increase in catecholamine hormonal levels.
7. At the cellular level caffeine blocks phosphodiesterases, promoting cyclic adenosine monophosphate (cAMP) accumulation thereby increasing ventilatory drive, increase in chemoreceptor sensitivity to carbon dioxide and this may be the cause for appropriate changes seen in respiratory parameters after caffeine consumption.

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