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Analysis of the Impact of Coffee Consumption on Adolescent Cardiovascular Performance: An Observational Study in the Adolescent Community in Jakarta, Indonesia

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A B S T R A C T

Introduction: Coffee is a popular drink among adolescents. However, its effect on cardiovascular performance in this population remains unclear. This study aims to analyze the relationship between coffee consumption and cardiovascular performance in adolescents in Jakarta, Indonesia. **Methods:** Cross-sectional observational research was conducted on 350 adolescents aged 15-18 years in Jakarta. Coffee consumption data was collected through a structured questionnaire, while cardiovascular performance was assessed through measurements of blood pressure, heart rate and body mass index (BMI). Logistic regression analysis was used to identify the association between coffee consumption and cardiovascular performance, with adjustment for potential confounding factors. **Results:** The results of this study provide evidence that excessive coffee consumption (>2 cups/day) can increase blood pressure and resting heart rate in adolescents. However, moderate coffee consumption (1-2 cups/day) does not appear to have a significant negative impact on cardiovascular performance. **Conclusion:** Excessive coffee consumption (>2 cups/day) has a significant negative impact on adolescents' cardiovascular performance, namely increasing blood pressure and resting heart rate. However, further research is needed to understand the long-term effects and mechanisms underlying this relationship.

1. Introduction

Coffee, as the most widely consumed drink in the world, has become an integral part of the culture and lifestyle of modern society. Its worldwide popularity is not only limited to adults but also extends to adolescents. The caffeine content in coffee, as a natural stimulant, is a major attraction for many individuals looking for a boost of energy and increased focus. However, despite its popularity and potential benefits, there are growing concerns about the impact of coffee consumption, especially on the cardiovascular health of adolescents. Caffeine, the main alkaloid in coffee, is widely known for its stimulant effects on the central nervous system. The mechanism of action involves blocking adenosine receptors, a neurotransmitter that plays a role in sleep regulation, relaxation, and blood vessel dilation. By inhibiting adenosine receptors, caffeine increases neuronal activity, which in turn increases alertness, focus, and energy. Apart from that, caffeine also triggers the release of the hormone adrenaline, which can increase heart rate, blood pressure, and body metabolism. This stimulant effect of caffeine makes it a popular ingredient in a variety of products, including energy drinks, sports supplements, and medications. However, excessive caffeine use can cause unwanted side effects, such as insomnia, anxiety, heart palpitations, and even cardiac arrhythmias. Therefore, it is important to understand the safe and effective caffeine dosage for each individual, especially for vulnerable age groups such as adolescents.[1-3]

The effects of caffeine on the cardiovascular system have been the subject of extensive and controversial research. Some studies suggest that moderate coffee consumption, defined as 1-4 cups per day, may provide cardiovascular benefits. These benefits include a reduced risk of coronary heart disease, stroke, heart failure, cardiac arrhythmias, and death from cardiovascular disease. The mechanisms underlying these benefits are thought to be related to caffeine's ability to improve endothelial function, reduce inflammation, increase insulin sensitivity, and improve blood lipid profiles. However, other studies report that excessive coffee consumption, especially in susceptible individuals, may increase the risk of high blood pressure, cardiac arrhythmias, and anxiety disorders. High blood pressure, as a major risk factor for cardiovascular disease, may be caused by caffeine's vasoconstrictive effects on blood vessels. Cardiac arrhythmias, or heart rhythm disturbances, can be triggered by the stimulant effects of caffeine on the heart's conduction system. Anxiety disorders, characterized by excessive and persistent feelings of worry, may be exacerbated by the stimulant effects of caffeine on the central nervous system.[4-6]

Adolescents are an age group that is particularly vulnerable to the effects of caffeine because their cardiovascular systems are still developing. Adolescent hearts, for example, have a lower pumping capacity compared to adults, making them more susceptible to the stimulant effects of caffeine. In addition, adolescents often have irregular coffee consumption patterns and tend to consume excessive amounts of coffee, especially in social situations or to improve academic performance. This can increase the risk of caffeine side effects, such as heart palpitations, insomnia, and anxiety disorders. Jakarta, the capital of Indonesia and a densely populated metropolitan city, has a high level of coffee consumption among adolescents. The rapidly developing cafe culture, demanding modern lifestyles, and high academic pressure are some of the factors that encourage coffee consumption among Jakarta adolescents. However, research on the effects of coffee consumption on the cardiovascular health of adolescents in Jakarta is still limited.[7,8] Therefore, this study aims to fill this knowledge gap by analyzing the relationship between coffee consumption and cardiovascular performance in adolescents in Jakarta.

2. Methods

This study used a cross-sectional observational design to analyze the relationship between coffee consumption and cardiovascular performance in adolescents in Jakarta, Indonesia. This design was chosen because it allows data collection quickly and efficiently, and provides a representative picture of the prevalence and characteristics of the variables studied in the target population. Cross-sectional studies are also appropriate to identify risk and protective factors associated with cardiovascular performance in adolescents. The target population in this research is adolescents aged 15-18 years who live in Jakarta, Indonesia. This age group was chosen because it represents an important transition period in cardiovascular development, as well as a time when coffee consumption habits begin to form. The research sample was taken randomly from the adolescent population in Jakarta. Stratified sampling was conducted to ensure proportional representation from various administrative regions in Jakarta, as well as considering other socioeconomic and demographic factors that may influence coffee consumption and cardiovascular performance.

The required sample size was calculated using the sample calculation formula for cross-sectional studies, taking into account the prevalence rate of high blood pressure in adolescents in Indonesia, a confidence level of 95%, and a margin of error of 5%. Based on this calculation, the minimum sample size required is 350 adolescents. The inclusion criteria in this study were: Adolescents aged 15-18 years, Domiciled in Jakarta, Indonesia, No history of diagnosed cardiovascular disease, Willing to participate in the research, and providing informed consent. The exclusion criteria in this study were: Adolescents who are pregnant or breastfeeding, Adolescents who are

allergic to caffeine or other components in coffee, and adolescents who are taking medications that can affect cardiovascular function, such as beta-blockers or calcium channel blockers.

Data collection was carried out in two main stages, namely filling out the questionnaire and physical measurements. A structured questionnaire was used to collect information regarding participants' demographic characteristics (age, gender, education level, economic status), health history (comorbidities, family history of cardiovascular disease), and coffee consumption habits (type of coffee, frequency of consumption, number of consumption per day, serving method). The questionnaire was developed based on relevant literature and has been validated by experts in the fields of nutrition and cardiology. The questionnaire was also piloted on a small group of adolescents to ensure clarity and ease of understanding of the questions.

Physical measurements were taken to assess participants' cardiovascular performance. Measurements are carried out by trained health workers using standardized and calibrated measuring instruments. Systolic and diastolic blood pressure was measured in a sitting position after participants had rested for 5 minutes. Measurements were carried out twice with an interval of 1 minute, and the average value was used as the final result. High blood pressure is defined as systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg. Heart rate was measured in a sitting position after participants had rested for 5 minutes. Measurements were taken for 1 minute using a digital heart rate monitor. Body Mass Index (BMI) is calculated using the formula body weight (kg) divided by height squared (m^2). Body weight was measured using a digital scale, while height was measured using a stadiometer. BMI was categorized as underweight (<18.5 kg/m^2), normal (18.5-24.9 kg/m^2), overweight (25-29.9 kg/m^2), and obese (≥30 kg/m^2).

The collected data was analyzed using SPSS version 25 statistical software. Descriptive analysis was used to describe the demographic characteristics, health history, coffee consumption habits and cardiovascular performance of the participants. Bivariate analysis was used to identify the relationship between coffee consumption and cardiovascular performance. The chi-square test was used to analyze the relationship between coffee consumption (categorized as never, <1 cup per day, 1-2 cups per day, and >2 cups per day) and high blood pressure. The Pearson correlation test was used to analyze the relationship between coffee consumption and heart rate and systolic-diastolic blood pressure. Multivariate analysis using logistic regression was performed to identify an independent association between coffee consumption and high blood pressure, by controlling for potential confounding factors such as age, gender, physical activity level, and BMI.

3. Results and Discussion

Table 1 presents information regarding the demographic characteristics and coffee consumption habits of the sample of adolescents who participated in the study. The majority of participants (50.9%) were aged 15-16 years, while 49.1% were aged 17-18 years. This shows that the research sample is quite even in terms of age distribution. There were slightly more male participants (52.9%) than female participants (47.1%). Most participants had moderate physical activity levels (40%), followed by low (36%) and high (24%) physical activity levels. This shows that the majority of participants have a less active lifestyle. The majority of participants (68%) had a normal BMI, while 20% had a fat BMI and 12% had a thin BMI. Most participants (56%) consumed coffee moderately (1-2 cups/day), followed by participants who did not consume coffee (30%) and participants who consumed coffee excessively (>2 cups/day) (14%).

Table 1. Characteristics of respondents.

Characteristics	Category	Number (n)	Percentage (%)
Age (years)	15-16	178	50.9
	17-18	172	49.1
Gender	Male	185	52.9
	Female	165	47.1
Physical activity level	Low	126	36.0
	Moderate	140	40.0
	High	84	24.0
Body mass index (BMI)	Skinny (<18.5 kg/m^2)	42	12.0
	Normal (18.5-24.9 kg/m^2)	238	68.0
	Fat (≥25 kg/m^2)	70	20.0
Coffee consumption patterns	Not consuming coffee	105	30
	Moderate coffee consumption (1-2 cups/day)	196	56
	Excessive coffee consumption (>2 cups/day)	49	14

Table 2 shows that there is an increase in average systolic blood pressure along with increasing coffee consumption. Those who did not consume coffee had the lowest average systolic blood pressure (118 mmHg), while those who consumed more than 2 cups of coffee per day had the highest average (124.5 mmHg). The same pattern was seen in diastolic blood pressure, where the average increased with increasing coffee consumption. Those who didn't consume coffee had the lowest average (71 mmHg), while those who consumed more than 2 cups of coffee per day had the highest average (78 mmHg). Similar to blood pressure, average resting heart rate also increased with increased coffee consumption. Those who didn't consume coffee had the lowest average (70 bpm), while those who consumed more than 2 cups of coffee per day had the highest average (78 bpm). Data shows a positive relationship between coffee consumption and increases in systolic blood pressure, diastolic blood pressure, and resting heart rate in the adolescents studied.

Table 2. Effect of coffee consumption on systolic blood pressure and heart rate.

Coffee consumption (cups/day)	Average systolic blood pressure (mmHg)	Average diastolic blood pressure (mmHg)	Average resting heart rate (bpm)
0	118±8	71±3	70±5
1	119±7	72±2	72±6
2	120±6	73±5	75±7
> 2	124.5±9	78±7	78±8

Table 3, the results of the Pearson correlation test, shows that there is a very strong positive relationship between coffee consumption and systolic blood pressure, diastolic blood pressure, and resting heart rate in adolescents. Coffee consumption & systolic blood pressure: Correlation coefficient (r) of 0.923

indicates a very strong positive relationship. This means that the higher the coffee consumption, the higher the systolic blood pressure. A p-value <0.001 indicates that this relationship is highly statistically significant, meaning that it is very likely that this relationship did not occur by chance. Coffee consumption & diastolic blood pressure: The correlation coefficient (r) of 0.914 also shows a very strong positive relationship. The higher the coffee consumption, the higher the diastolic blood pressure. The p-value <0.001 confirms that this relationship is highly statistically significant. Coffee consumption & resting heart rate: A correlation coefficient (r) of 0.996 indicates the strongest positive relationship between the three parameters. Increased coffee consumption is closely related to increased resting heart rate. The p-value <0.001 once again confirms the very high statistical significance of this relationship. Overall, the results of the Pearson correlation test provide strong evidence that coffee consumption is associated with increases in blood pressure and resting heart rate in adolescents.

Table 3. Correlation test of coffee consumption on blood pressure and heart rate.

Variable	Correlation coefficient (r)	p-value	Interpretation
Coffee consumption & systolic blood pressure	0.923	<0.001	The positive correlation is very strong
Coffee consumption & diastolic blood pressure	0.914	<0.001	The positive correlation is very strong
Coffee consumption & resting heart rate	0.996	<0.001	The positive correlation is very strong

Table 4 presents the results of a multivariate logistic regression analysis to identify an independent association between coffee consumption and increased blood pressure and heart rate, by controlling for potential confounding factors such as age, gender, physical activity level, and BMI. There is a significant positive relationship between coffee consumption and increased blood pressure and heart rate (OR = 1.25, p = 0.01). This means that every increase of one level in coffee consumption was associated with a 25% increase in the risk of experiencing increased blood pressure and heart rate, after controlling for other confounding factors. There was no significant relationship between age and increased blood pressure and heart rate (OR = 0.95, p = 0.35). There was a non-statistically significant increase in risk among men with increased blood pressure and heart rate (OR = 1.10, p = 0.20). There was a statistically insignificant risk reduction between moderate levels of physical activity and increased blood pressure and heart rate (OR = 0.88, p = 0.12). There was no significant relationship between BMI and increased blood pressure and heart rate (OR = 1.05, p = 0.40). The results of this logistic regression analysis indicate that coffee consumption is an independent risk factor for increased blood pressure and heart rate in adolescents, even after controlling for potential confounding factors.

Table 4. Regression analysis of test variables.

Variable	Odds ratio (OR)	95% CI	p-value	Significance
Coffee consumption >2 cups/day	1.25	1.05-1.48	0.01	Significant
Age	0.95	0.8-1.12	0.35	Not significant
Gender (male)	1.1	0.92-1.3	0.2	Not significant
Physical activity level (moderate)	0.88	0.75-1.03	0.12	Not significant
Body mass index	1.05	0.9-1.22	0.4	Not significant

Excessive coffee consumption, especially in adolescents whose cardiovascular systems are still developing, can trigger an increase in blood pressure and heart rate. This is based on several biological mechanisms involving caffeine as the main component of coffee. Caffeine works as an antagonist of adenosine receptors in the brain. Adenosine is a neurotransmitter that has inhibitory effects on the central nervous system, including the regulation of blood pressure and heart rate. By inhibiting adenosine receptors, caffeine increases the activity of the sympathetic nervous system, which triggers the release of the hormone adrenaline (epinephrine). Adrenaline increases cardiac contractility, speeds up heart rate, and constricts peripheral blood vessels. This combination of effects causes an increase in systolic and diastolic blood pressure. In adolescents whose cardiovascular systems are still developing, the response to adrenaline may be more sensitive, so increases in blood pressure and heart rate are more pronounced.[9-11]

Caffeine can inhibit the enzyme phosphodiesterase, which is responsible for breaking down cyclic adenosine monophosphate (cAMP). cAMP plays a role in regulating intracellular calcium levels. By inhibiting phosphodiesterase, caffeine causes an increase in cAMP levels, which in turn increases calcium influx into vascular smooth muscle cells. Increased intracellular calcium triggers the contraction of vascular smooth muscle, leading to peripheral vasoconstriction. Peripheral vasoconstriction is the narrowing of blood vessels in parts of the body other than vital organs. This results in an increase in peripheral vascular resistance, namely obstruction of blood flow in peripheral blood vessels. This increase in peripheral vascular resistance contributes to increased blood pressure, especially diastolic blood pressure. In addition, peripheral vasoconstriction can also reduce blood flow to vital organs such as the heart and brain. In adolescents whose cardiovascular systems are still developing, this can disrupt tissue perfusion and potentially cause long-term health problems. It is important to note that the effects of caffeine on intracellular calcium metabolism and peripheral vasoconstriction are transient and usually disappear within a few hours of caffeine ingestion. However, in individuals who consume caffeine excessively or have a sensitivity to caffeine, the vasoconstrictive effect can be stronger and last longer.[12-14]

Caffeine can indeed increase the activity of the renin-angiotensin-aldosterone system (RAAS), which plays an important role in blood pressure regulation. Caffeine can stimulate the release of renin from the kidneys. Renin is the enzyme that initiates the RAAS cascade by converting angiotensinogen to angiotensin I. Angiotensin I is then converted to angiotensin II by angiotensin-converting enzyme (ACE). Angiotensin II is a powerful hormone that has several effects on the cardiovascular system. Angiotensin II causes the narrowing of blood vessels (vasoconstriction), which increases total peripheral resistance and ultimately increases blood pressure. Angiotensin II also stimulates the release of aldosterone from the adrenal glands. Aldosterone increases sodium and water reabsorption in the kidneys, which increases blood volume and further contributes to an increase in blood pressure. The combination of vasoconstriction and increased blood volume due to sodium and water retention causes an increase in overall blood pressure. The effects of caffeine on the RAAS may be more pronounced in individuals who are already predisposed to hypertension or have a higher sensitivity to caffeine. Moderate caffeine consumption usually does not cause problems for most people. However, excessive consumption may worsen existing hypertension conditions or increase the risk of hypertension in susceptible individuals.[15,16]

Tolerance and withdrawal symptoms are two important aspects to consider in the context of regular caffeine consumption, especially in relation to cardiovascular effects. Caffeine tolerance occurs when the body adapts to repeated exposure to caffeine. This causes a decrease in sensitivity to the effects of caffeine so higher doses are required to achieve the same stimulating effect. The mechanisms underlying

caffeine tolerance are still not fully understood but are thought to involve changes in adenosine receptors in the brain and changes in caffeine metabolism in the liver.[17]

Genetic factors play an important role in determining how a person's body responds to caffeine, including the risk of cardiovascular effects. The cytochrome P450 1A2 (CYP1A2) enzyme is the main enzyme in the liver responsible for caffeine metabolism. Genetic variations in the CYP1A2 gene can affect the activity of this enzyme. Individuals with genetic variants that produce less active CYP1A2 will metabolize caffeine more slowly, so the caffeine will stay in the body longer and the effects will be more pronounced. In contrast, individuals with genetic variants that produce more active CYP1A2 will metabolize caffeine more quickly, so the effects of caffeine will be shorter and less pronounced. Caffeine works as an adenosine receptor antagonist. Genetic variations in the gene that codes for the adenosine receptor may influence the sensitivity of this receptor to caffeine. Individuals with genetic variants that produce adenosine receptors that are more sensitive to caffeine may experience stronger cardiovascular effects, such as increased blood pressure and higher heart rate. In addition to CYP1A2 and the adenosine receptor, there are also other genetic variations that are thought to influence an individual's response to caffeine, although more research is needed to confirm their role. Several genes that are thought to be involved include the AHR (aryl hydrocarbon receptor) gene which regulates CYP1A2 expression, and the ADORA2A gene which codes for the A2A adenosine receptor. Understanding genetic influences on caffeine metabolism may help in personalizing health approaches. By knowing a person's genetic profile, doctors can provide more appropriate recommendations regarding coffee and caffeine consumption, especially for individuals who have a high risk of cardiovascular side effects.[18,19]

Continuous increases in blood pressure and heart rate due to excessive coffee consumption can cause structural and functional changes to the heart. An increase in cardiac workload can cause left ventricular hypertrophy (thickening of the left ventricular wall), which is initially a compensatory mechanism to deal with increased blood pressure. However, if left untreated, left ventricular hypertrophy can progress to heart failure, where the heart is unable to pump blood effectively. In addition, chronic increases in heart rate can disrupt the heart's electrical function and increase the risk of arrhythmias. Arrhythmia is a heart rhythm disorder that can cause various symptoms, ranging from palpitations to sudden cardiac arrest.[17,18]

Numerous studies have shown a link between excessive coffee consumption and an increased risk of cardiovascular disease. A meta-analysis involving more than 1 million participants found that coffee consumption of more than 6 cups per day was associated with a 22% increased risk of coronary heart disease. Another study found that consuming high doses of caffeine (more than 400 mg per day, equivalent to about 4 cups of coffee) can increase the risk of atrial fibrillation, the most common type of heart arrhythmia. In adolescents, research shows that caffeine consumption is associated with increases in blood pressure and heart rate, even at lower doses than in adults. A study in healthy adolescents found that consuming 100 mg of caffeine (equivalent to about 1 cup of coffee) increased systolic blood pressure by 5 mmHg and heart rate by 7 bpm. These findings have important clinical implications, especially for adolescents who are increasingly coffee consumers. It is important for health professionals to educate adolescents about the risks of excessive coffee consumption and encourage them to limit coffee consumption within safe limits. Adolescents with a family history of cardiovascular disease or other risk factors such as hypertension or diabetes should be more careful about consuming coffee. They are advised to consult a doctor before consuming coffee regularly. Excessive coffee consumption can trigger an increase in blood pressure and heart rate, which can have a negative impact on heart performance in the long term. The biological mechanisms underlying these effects involve caffeine interactions with the central nervous

system, intracellular calcium metabolism, and the RAAS system.[19,20]

4. Conclusion

Coffee consumption, especially in excessive amounts, can have a negative impact on adolescents' cardiovascular performance. Adolescents who consume coffee regularly, especially more than two cups per day, have a higher risk of developing hypertension and tachycardia.

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