Original Article

Expiratory Carbon Monoxide Levels of Cigarette Smokers in College Environment

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Abstract

Background: The impact of smoking is still a huge problem in the world. The use of cigarettes is one of the biggest causes of death that can be prevented. One of the harmful substances of smoking is carbon monoxide (CO). Unfortunately, research comparing CO levels in white and Kretek cigarette smokers among college students in Indonesia has not been conducted. This study aims to determine the relationship of expiratory CO levels in male students who smoke white or Kretek cigarettes at a university in Depok using a CO analyzer and questionnaire.

Methods: This is a cross-sectional study design with 108 samples divided into two groups of white cigarette smokers and Kretek cigarette smokers with consecutive sampling techniques. Subjects took the expiratory CO test using a CO analyzer and filled out questionnaires related to smoking and other factors.

Results: The study found expiratory CO results in white cigarette smokers at 13.9±8.36 ppm and Kretek cigarette at 13.18±8.79 ppm with no significant relation statistically. The factor that influences the subject's CO expiration is the Brinkman Index (P<0.001) with a weak correlation result and factors that influence the choice of cigarette type, namely pocket money (P=0.023) and age (P=0.015).

Conclusion: There was no statistically significant relationship between the average of white cigarette smokers or Kretek cigarette smokers with expiratory CO levels in subjects. This might be due to a more significant effect on the number of cigarettes consumed. Seeing the trend in Indonesia that Kretek cigarettes are relatively cheaper than white cigarettes, money allowance is one of the factors that determine the choice of white or Kretek cigarettes for college students in Depok.

Keywords: Brinkman index, carbon monoxide, college students, Kretek cigarettes, white cigarettes

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INTRODUCTION

There are more than seven million deaths worldwide every year due to direct or indirect tobacco use.[1] Approximately 1.1 billion people smoke globally, with 80% of them coming from the lower to middle-income population.[2] Indonesia, as a developing country, ranks third in the world for the largest tobacco consumption, following China and India. In Indonesia, 76.1% of males above the age of 15 are smokers, and the province with the highest smoking prevalence is West Java (32.7%).[2,3] Various types of cigarettes are accessible to the public, including white cigarettes, clove cigarettes (Kretek), and hand-rolled cigarettes (linting).[2]

The use of cigarettes or tobacco is one of the major preventable causes of death. However, the affordable price, widespread availability of products, and lack of awareness about the dangers of smoking contribute to the increasing number of smokers.[2] One of the indicators used to differentiate between non-smokers and smokers is the level of CO in their exhaled breath.[4] This level correlates with the frequency and type of cigarettes smoked.[5] Studies have compared the levels of exhaled CO between regular smokers and those who smoke "light" cigarettes, as well as between smokers using filtered and non-filtered cigarettes.[6,7]

In Indonesia, the majority of smokers prefer Kretek cigarettes or hand-rolled cigarettes, accounting for 93.7% of smokers compared to only

3.70% who smoke white cigarettes.[8] Research comparing the exhaled CO levels of Kretek and white cigarette smokers has shown that subjectively Kretek cigarettes are more preferred, making them attractive to the younger population to start smoking.[8]

Carbon monoxide is a substance composed of one carbon atom and one oxygen atom bonded together. It is formed and released into the atmosphere due to incomplete combustion processes of carbon-based materials. Carbon monoxide is the second most abundant pollutant in the human environment.[9] Under normal conditions, it is a colorless, odorless, and tasteless gas. It has various effects on humans. Typically, victims of CO poisoning will lose consciousness before realizing they are being affected by it.[9]

The effects of CO on the human body are related to hemoglobin (Hb) and how the body uses Hb to distribute oxygen as one of the body's energy sources. When we inhale CO, it enters the lung's alveoli and comes into contact with the lung's blood vessels. Carbon monoxide binds to Hb more easily than oxygen does. This is because Hb has a higher affinity for CO (220% affinity of Hb for oxygen) and forms carboxyhemoglobin. In this condition, CO is not utilized by the body in the respiratory process. Therefore, at high levels, carboxyhemoglobin in the blood leads to cellular hypoxia (lack of oxygen within cells).[9]

Carbon monoxide can also bind to the heme protein in the structure of cytochrome c oxidase during the electron transport phase, inhibiting aerobic respiration processes by mitochondria. Carboxyhemoglobin also increases the affinity of other heme molecules within the carboxyhemoglobin for oxygen. This shifts the oxygen-hemoglobin dissociation curve, making it more difficult for hemoglobin to release oxygen in areas of the body that need it, such as muscles and the brain, resulting in a condition of oxygen deficiency in the respiratory process.[9]

Carbon monoxide can enter our bodies through inhalation. Generally, inhalation poisoning occurs during fire incidents, and two-thirds of deaths caused by fires are due to or supported by CO poisoning.[10] One study stated that the lower limit of carboxyhemoglobin levels for smokers and non-smokers differs by 8%, which is 10% for smokers and 2% for non-smokers.[11] There are case studies of a smoker patient experiencing recurrent CO poisoning, leading to cognitive impairment.[12]

White cigarettes are tobacco cigarettes without a clove mixture, unlike Kretek cigarettes which contain cloves. These white cigarettes are not from Indonesia; they are imported from abroad and have gradually gained demand in the domestic economy.[13]

Generally, white cigarettes have lower tar and nicotine content compared to Kretek cigarettes. They lack the distinctive flavor of Kretek due to the absence of a tobacco blend mixed with cloves. White cigarettes are consumed by people in various countries around the world. However, in Indonesia, only about 3.7% of people smoke white cigarettes, compared to 80.4% who smoke Kretek cigarettes exclusively. This is because the taste is not as suitable for the Indonesian palate, and white cigarettes are relatively more expensive than Kretek cigarettes.[2]

Kretek cigarettes are cigarettes with or without filters that use tobacco as the main ingredient, mixed with cloves and rolled in cigarette paper. In the 1980s, the ratio of Kretek cigarette consumption to white cigarette consumption was 1:9, but now it has reversed and is even more than 9:1. This shift is due to higher consumption of Kretek cigarettes and the public's interest in them. Kretek cigarettes derive their name from the "Kretek" sound produced by burning cloves when the cigarette is smoked, and they have a distinctive aroma and taste. When comparing the nicotine and tar content of various brands of Kretek and white cigarettes, Kretek cigarettes have nearly five times the nicotine content and up to three times the tar content compared to white cigarettes.[14]

Kretek cigarettes release more harmful substances compared to white cigarettes, including nicotine, CO, and other compounds.[8] Is there a difference in the long term between the levels of CO in active smokers of white cigarettes and active

smokers of Kretek cigarettes? In a study conducted in 2007, the CO levels in smokers of white cigarettes with filters were higher than those in smokers of white cigarettes without filters, indicating a higher release of CO in filtered cigarettes.[7] There is also a possibility of differences in CO exhalation levels between smokers of Kretek cigarettes with and without filters.

Exhaled CO levels in smokers can indicate validation of abstinence or non-consumption.[15] When smoking, CO, a product of incomplete combustion, is quickly absorbed by the blood. During respiration, some of the CO is released and can be detected by the device.[16] Exhaled CO monitors measure in parts per million (ppm).[17] Carbon monoxide *parts per million* (ppm) in exhaled CO indicates the level of carboxyhemoglobin in the blood or the percentage of blood cells carrying CO compared to oxygen.[16]

Smokers have higher CO levels in their exhalation. Other conditions that can increase exhaled CO levels include patients with COPD, OSA, asthma, and those living in areas with high air pollution.[16] Different tobacco use habits can also result in varying CO increases, such as with shisha, cigars, and pipes.[16] Therefore, the authors aim to examine the effects of CO elevation in Kretek and white cigarette smokers.

Several studies have been conducted on the differences, but measurements of exhaled CO levels have not been widely studied.[2] Based on the researchers' review of the student population, research on CO levels in Kretek and white cigarette smokers has not been conducted. Therefore, we aim to conduct a study to find differences in exhaled CO levels among male students in Depok. We chose this area because Depok is part of a province with the highest prevalence of smokers in Indonesia. This study also considers the differences in CO levels between Kretek and white cigarette smokers to observe the long-term effects of smoking both types of cigarettes based on their exhaled CO levels.

METHODS

This study is a cross-sectional study designed to compare the smoking habits of white and Kretek cigarette smokers with their exhaled CO levels simultaneously. The study was conducted from August to November 2019 within university campus environments in Depok, with research ethics approval from The Ethics Committee of the Faculty of Medicine, Universitas Indonesia (approval letter number KET-864/UN2.F1/ETIK/PPM.00.02/2019).

This study aims to explore the relationship between the smoking habits of white or Kretek cigarettes as the independent variable and the exhaled CO levels as the dependent variable. Additionally, the study also aims to identify the relationships among variables that influence the outcome (smoking patterns, number of cigarettes per day, duration of smoking, age, body mass index, allowance, and smoking habits in the environment) about both independent and dependent variables. The instruments used to assess these variables are questionnaires and a CO Analyzer device.

The data used in this study are primary data obtained through interviews using questionnaires and examinations using a CO Analyzer (ToxCO Bedfont) to measure exhaled CO levels in groups of white and Kretek cigarette smokers. To use a CO breath test, first, subjects are asked to inhale fully. Then hold the breath for 10-15 seconds followed by slowly blowing out all the air into the mouthpiece of the CO monitor. The monitor will display CO results in ppm. Interpretation of the CO measurements is 7-10 ppm smoker, 11-19 ppm light smoker (less than 20 cigarettes per day), 20-35 ppm smoke more than 20 cigarettes per day, and 36-49 ppm heavy smoker (more than 35 cigarettes per day).

The data were collected from male student subjects who agreed to participate as respondents within the university environment in Depok, West Java. Inclusion criteria included subjects being undergraduate students who smoked either white or Kretek cigarettes with the frequency of smoking either of them greater than 80% of total cigarettes consumed, and they signed an informed consent form. White smokers are students who smoke white cigarettes which are tobacco cigarettes without clove mixture. Kretek smokers are students who smoke Kretek cigarettes that use tobacco as the main

ingredient, mixed with cloves, and rolled in cigarette paper. The minimum sample size for this study was 54 for each group, resulting in a total of 108 subjects. The significant difference sought in exhaled CO levels was 5 ppm.

The method of sample data collection utilized nonprobability sampling, employing either consecutive sampling or quota sampling techniques. In this approach, subjects who met the selection criteria provided their data until the required quota of subjects was reached. The data obtained from the samples will be processed using statistical analysis software, specifically SPSS 22.

RESULTS

A total of 124 subjects were obtained; however, 16 data points could not be used because the subjects smoked a combination of white and Kretek cigarettes. Data were divided into two groups: the white cigarette smokers group and the Kretek cigarette smokers group. The demographic data of the subjects are presented in Table 1.

Table 1. Demographic Characteristics (N=108)

Characteristics	N	%
Age, years [median (min-max)]	20 (17–24)	
Body Mass Index (mean±SD)	24.15±4.44	
Underweight	9	8.3
Normal	40	37
Overweight	16	14.8
Obese	43	39.8
Educational Background		
Natural Sciences	45	41.7
Social Sciences	63	58.3
Monthly Allowance		
<Rp2,000,000.00	28	25.9
Rp2,000,000.00–Rp4,000,000.00	38	31.1
Rp4,000,000.00–Rp6,000,000.00	14	12.9
>Rp6,000,000.00	28	25.9
Brinkman Index [median (min-max)]	40 (1–280)	
Smoking Habits		
White Cigarettes	48	50
Kretek Cigarettes	48	50
Smoking Inhalation Pattern		
Shallow	8	7.4
Deep	100	92.6
Smoking Habits of Closest People		
Immediate Family	71	65.7
Friends	107	99

The mean CO levels were 13.9±8.36 ppm in white cigarette smokers and 13.18±8.79 ppm in Kretek cigarette smokers. The Brinkman index for white cigarette smokers was 42.5 (2–280), while for Kretek cigarette smokers, it was 40 (1–144). These values indicate that in both smoker populations, the CO levels do not significantly differ from the cutoff of 5 ppm. However, white cigarette smokers had slightly higher CO levels compared to Kretek cigarette smokers. The obtained Brinkman index also had a slightly different median between white and Kretek cigarette smokers.

The unpaired t-test results for the choice of white or Kretek cigarettes to CO levels showed non-significant differences. The inhalation patterns of the subjects can be observed in Figure 1, which shows a bar graph representing the subjects' inhalation patterns. Trends in the samples can be seen in the graph.

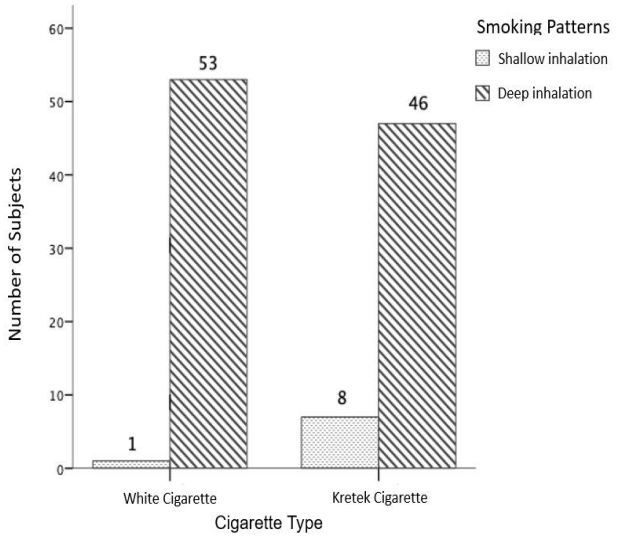

Figure 1. Subjects' Inhalation Patterns

Table 2 shows that the statistical analysis conducted was an Unpaired T-test. This choice was made because the normality test (Kolmogorov-Smirnov) indicated a normal distribution of the independent variable's data. Subsequently, an unpaired t-test was performed, and the results of this analysis showed p-values for both variables. It can be concluded that there is no significant relationship between the mean values of the two types of freely smoked cigarettes and the mean exhaled CO levels.

The results of the correlation analysis indicate that smoking habits in the Brinkman Index have a positive correlation with the subjects' CO levels. However, only a weak correlation with a value of r=0.350; *P*<0.001 (n=108).

Table 2. Relationship between Cigarette Type Preference and CO Levels

Cigarette Type	CO level (ppm)	*P**
White Cigarettes	13.9±8.36	0.663
Kretek Cigarettes	13.18±8.79	0.663

Note: *unpaired t-test

The Mann-Whitney comparison test for inhalation pattern variables with CO in the non-normally distributed data showed no significant relationship between the inhalation patterns and the subjects' CO levels (Table 3).

Table 3. Relationship between Smoking Patterns and CO Levels

Smoking Patterns	CO level (ppm)	*P**
Shallow inhalation	6 (2–33)	0.375
Deep inhalation	12.5 (2–40)	

Note: *Mann-Whitney Test

In this study, the relationship between BMI, allowance, and the influence of smoking from close surroundings on the choice of cigarette type was also analyzed. The analysis results showed no significant relationship between body mass index and the choice of cigarette type, friends, or immediate family members. However, the Chi-Square analysis for the relationship between allowance and cigarette type choice revealed a significant connection between students' allowance and the choice of cigarettes consumed (Table 4).

DISCUSSION

This study employed a non-probability sampling method using a consecutive sampling technique, meaning that the obtained samples do not provide a representation of the entire population in Depok. They only depict the demographic distribution of the subjects we acquired.

The average BMI obtained from the sampling process indicates that the majority of subjects fall into the obese category. This finding contradicts the study by Nattinee et al, which generally states that smokers tend to have lower BMI compared to non-smokers.[18] This discrepancy might be due to our non-random and purposive sampling technique, where subjects were selected based on specific criteria. There is a possibility that a majority of smokers in Depok are obese, although it could also be coincidental that the obtained subjects happened to be obese.

The subjects in this study had varied monthly allowances, and we couldn't conclude that students who smoked had higher allowances than others. This finding contradicts a study by the Health Promotion Administration of Taiwan, which stated that students who receive more allowance tend to have a higher tendency to smoke.[17,19]

Table 4. The relationship between BMI, allowance, and the influence of closest environment smoking on the choice of cigarette type

Characteristics	Cigarette Type		*P*
	White	Kretek	
BMI			
Underweight	2 (28.6%)	5 (71.4%)	0.350*
Normal	21 (53.8%)	18 (46.2%)	
Overweight	6 (31.6%)	13 (68.4%)	
Obese	25 (58.1%)	18 (41.9%)	
Allowance			
<Rp2,000,000.00	8 (27.6%)	21 (72.4%)	0.026**
Rp2,000,000.00–Rp4,000,000.00	21 (55.3%)	17 (44.7%)	
Rp4,000,000.00–Rp6,000,000.00	7 (50.0%)	7 (50.0%)	
>Rp6,000,000.00	18 (66.7%)	9 (33.3%)	
Close friend			
Have close friends who smoke	53 (49.5%)	54 (50.5%)	0.317**
Don't have close friends who smoke	1 (100.0%)	0 (0.0%)	
Immediate family			
Have immediate family members who smoke	34 (47.9%)	37 (52.1%)	0.543**
Don't have immediate family members who smoke	20 (54.1%)	17 (45.9%)	

Note: *Mann-Whitney Test; **Chi-Square Test

Similar to the BMI data, this discrepancy could be speculated as a result of our non-random sampling method, as not all smokers in the university in Depok were included in this study.

The subjects also predominantly have social connections with smokers, such as close friends and immediate family members. Approximately 65.7% of the subjects have immediate family members who smoke, while 99% have close friends who smoke. This aligns with a study by Waters et al, stating that more than two-thirds of campus smokers are social smokers, meaning they smoke more when people around them smoke.[20]

Hill et al also state that social status is a strong motivation for starting smoking; popularity and social acceptance can lead adolescents to make risky health decisions such as smoking and consuming alcoholic beverages. If popular individuals in the population engage in these habits, others are more likely to follow.[21] The family also plays a significant role in influencing the likelihood of teenagers smoking. Research by Robalino and Macy concludes that children in families with one or both parents who smoke are more likely to smoke themselves.[22] However, if parents manage their families well, do not involve their children in their smoking habits, and prohibit their children from smoking, the likelihood of their children smoking decreases.[21]

The smoking habits of the subjects were categorized into three aspects: cigarette choice, the degree of smoking habits measured by the Brinkman Index, and the inhalation pattern. Cigarette choice is a primary factor in this research as the variables under investigation depend on the subjects' choices. Given student preferences, Kretek cigarettes are more commonly consumed due to their widespread availability, sweeter taste, being "suitable for the Indonesian palate," and their lower price.[14]

This cigarette choice is the main variable that led the research to opt for consecutive sampling instead of random sampling. According to the Data and Information Center of the Indonesian Ministry of Health, the majority of people are significant smokers (93.7% smoke Kretek cigarettes), and the field conditions align with this information.[2] Researchers faced difficulties finding smokers who only smoked white cigarettes due to the reasons for choosing Kretek cigarettes mentioned above.

The degree of smoking habits among students can be assessed using the Brinkman Index (BI). When classified as light, moderate, and heavy smokers, all subjects obtained fell into the light smoker category, except for one subject classified as a moderate smoker.[15] This is because the subjects' smoking duration is relatively low, with some only starting to smoke during high school or college.

Shallow smoking, where the smoke is only inhaled into the mouth and not into the lungs, has a significant impact on health. Previous studies have proven that even if the smoke is not inhaled deeply into the lungs, it increases the risk of myocardial infarction and mortality.[23]

There is no significant relationship between the choice of cigarette type, either white or Kretek cigarettes, and the exhaled CO levels of the subjects. This finding contradicts the study by Malson et al, which discussed that CO absorption from clove cigarette consumption is higher than that from white cigarettes.[8] However, this aligns with the findings of Groman et al regarding cigarette choices with lower nicotine and tar levels, which are perceived as "lighter". In the Indonesian context, white cigarettes are considered lighter due to their lower nicotine and tar content. However, the research demonstrated that CO levels are even higher among individuals smoking these 'light' cigarettes.[6]

Variations in the research results might occur because the exhaled CO levels are influenced by numerous factors, one of which is the type of cigarette. However, smoking habits, cigarette brands, and tobacco content also play a role in determining exhaled CO levels. On the other hand, other external factors can influence the obtained CO levels, such as environmental pollution, physical activity after smoking, diet, and other lung conditions that may not have been disclosed or the subjects themselves may not be aware of.[24] The environmental conditions around Depok can be classified as urban areas with

a high number of motor vehicles, making them a potential source of CO pollution. In fact, in one study, the CO exposure level on the roadside reached up to 170 ppm.[25]

Another possible contributing factor to the different results from the study by Malson et al. is the degree of smoking habits. Kretek smokers have a Brinkman Index that is 20 points lower compared to white cigarette smokers. This indicates that the subjects' smoking habits impact the level of CO obtained, similar to previous research by Robinson and Forbes.[8] There is a possibility that Kretek smokers among our subjects have slightly lower CO levels compared to white cigarette smokers due to their lower smoking habits.

In contrast to the study conducted by the Health Promotion Administration of Taiwan, where the more allowance adolescents receive, the higher the likelihood of them smoking, our subjects showed different results.[19] Most of our subjects received between IDR 2,000,000.00–IDR 4,000,000.00 per month, accounting for 31.1%, while only 12.9% received between IDR 4,000,000.00–IDR 6,000,000.00, with the rest evenly distributed between less than two million and more than six million.[26]

This research found a significant relationship between allowance and cigarette choice. Considering the trend in Indonesia where white cigarettes are more expensive than Kretek cigarettes, we found a significant connection between students' allowance and their choice of cigarettes. Unfortunately, there hasn't been a study on allowance and cigarette choice. However, Slater et al concluded in their study that the lower the cigarette price, the more likely a population will smoke.[26] The smoking habits of close individuals, especially peers, have been identified as the strongest determinant of adolescent smoking, according to previous research in Kolkata, India.[27] According to Hill et al, parents also play a significant role in smoking habits and even initiate a child's smoking behavior.[21]

As shown in Table 4, more smokers have immediate family members who smoke compared to those who do not, and only one person does not have close friends who smoke. This is closely related to smoking habits, especially the initiation of smoking, affecting their Brinkman Index due to their environment. Unfortunately, there has been no previous research examining the relationship between environmental smoking habits and the choice of cigarette type. In this study, the significance of the influence of environmental smoking habits on the choice of cigarette type cannot be concluded due to insufficient data.

LIMITATIONS

The cross-sectional study used non-probability sampling with consecutive sampling where no randomization was possible due to the limitation to finding smoker students who only smoked white cigarettes or Kretek cigarettes. Another limitation was the timing to measure exhaled CO level that will influence the result of the exhaled CO level. It was difficult to collect CO data within 24 hours after the last cigarette exposure.

CONCLUSION

In this study, the CO levels in both white cigarette smokers and Kretek cigarette smokers were higher than the normal levels of non-smokers, despite all the sampled individuals being light smokers. There was no statistically significant relationship between the choice of white or Kretek cigarettes and exhaled CO levels in the subjects nor between smoking patterns and CO levels. However, there was a weak but significant correlation between the Brinkman Index and CO levels.

Further research on the characteristics of cigarette types and smoking patterns among young adults can aid in creating better policies related to anti-smoking campaigns among the youth for example in college students. Additionally, knowledge about CO and its health implications should be disseminated among educated students to raise awareness about the real impact of smoking from an early age.

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