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Diesel Particulate Matter Exposure Increased HbA1c and Apo-B Level in Blood on Motor Vehicle Testing Officer Cilincing Jakarta, Indonesia

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Abstract

Diesel particulate matter both fine and ultrafine particulate contribute to daily personal exposure of workers. Exposure to diesel particulate matter in the short term and long term can cause diabetes and atherosclerosis. These health problems include changes in glucose, HbA1c, lipids, and Apoliprotein-B (Apo-B). This study aimed to analyze the exposure of diesel particulate matter associated with increased HbA1c and Apo-B level in blood. The samples were a mechanical test and administrative officer totaling 33 people and 24 people as a comparison group. The research variables are diesel particulate matter exposure, HbA1c level, Apo-b level, age, body mass index (BMI), length of work, and smoking habit. Measurement of particulate matter exposure used Leland Legacy Pump and Sioutas Cascade Impactor. Calculation of exposure concentration used the gravimetric method. Measurements of HbA1c levels in the blood used HPLC Ion Changes method and for Apo-B, it used Polyethyleneglycol (PEG) enhanced immunoturbidimetric assay. The results were mean of Apo-B level in mechanic test officer is 107.30 and in control groups, it's 91.17 mg/dL. It showed that Apo-B level in mechanic test officer was higher than Apo-B level in control groups. The HbA1c level in blood had ranged from 4.90 % - 6.80 %. mg/dL. The results showed there was a positive correlation among the personal exposure concentrations of PM_{10}, $PM_{2.5}$, PM_1, $PM_{0.5}$ and $PM_{0.25}$ with levels of HbA1c in the blood. In this study, sex, age, and BMI were also an independent factor that could increase the HbA1c level. Furthermore, this study also found that sex, age, smoking habit, and BMI also contributed to increasing Apo-B level in blood.

Keywords: Diesel Particulate Matter, HbA1c, Apo-B, Vehicle Testing Officer

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1. Introduction

Motor vehicle emissions are one of the largest sources of particulate matter, especially diesel-engined vehicles. Diesel engines that are widely used for the transportation industry have the potential to emit exhaust gas (gas exhaust) which contains a mixture of gas and very small particles that harmful for human health. Diesel exhaust is emitted

from various on-road diesel engines such as diesel trucks, buses and cars and off-road diesel engines such as locomotives, ships, and heavy equipment. Particulate components of diesel exhaust is a mixture of black carbon, organic carbon elements, sulfates, metals and trace elements known as Diesel Particulate Matter [1]. In June 2012, The International Agency for Cancer Research (IARC) classified Diesel Exhaust including Diesel Particulate Matter (DPM) as the human carcinogen group 1 [1]. The tiny particle size of diesel particulate matter can reach inside of the lungs and cause toxic effects [2]. Every 1 μg/m^3 increase of particle exposure concentration from diesel exhaust is associated with 7.000 premature deaths per year in the United States [3].

The long-term exposure of $PM_{2.5}$ from inhaled air, even at low concentrations is also associated with an increased risk of dying from diabetes [4]. Diabetics associated to cardiovascular risk have twice the risk of exposure to PM_{10}inhalation compared with non-diabetics [5]. Acute or chronic exposure to particulate matter (PM) also can increase the incidence of cardiovascular disease. Acute exposure may lead to acute myocardial infarction, ischemic stroke, and congestive heart failure. Chronic exposure of PM may lead to the incidence of atherosclerosis as evidenced in the American Cancer Society cohort study, every 10 μg/m3 increase of $PM_{2.5}$ leads to a 12% increase in death from cardiovascular disease [6].

Medium exposure of particulate matter is associated with to changes in glucose, HbA1c, and lipids especially in people with diabetes [7]. HbA1c is a glucose indicator of homeostasis in diabetes, previous studies have found that particulate matter exposure is associated with increased HbA1c [8 - 11]. Meanwhile, the previous study found that the level of Apo-B and Apo A-I could be used as the better predictor of cardiovascular disease than predict it with cholesterol concentration. Apo-B can describe the presence of atherogenic particles containing Apo-B. Apo-B is not only found in Low-Density Lipoprotein (LDL) but also in Very Low-Density Lipoprotein (VLDL) and Intermediate-Density Lipoprotein (IDL) [12]. A study by Sniderman, et al. suggests that Apo-B analysis can predict concentrations of LDL particles because LDL and VLDL particles contain a single molecule of Apo-B protein and more than 90% Apo-B is in LDL [13].

Motor vehicle testing center is one of the workplaces with high particulate exposure. Previous studies conducted at the Pulogadung and Ujung Menteng motor vehicle testing center found that the particle exposure of PM2.5 was high in both places [14]. While for the results of blood tests, it was found that there was an increase in cholesterol, triglyceride and HbA1c levels in the blood of mechanical officers in both motor vehicle testing center. Cilincing vehicle testing centre is one of the motor vehicle testing centre in Jakarta which carries out vehicle testing with the type of vehicle designation specifically, including tractor heads, dump trucks, trucks equipped with coupling, trailer, tank, truck mixer, crane and CBU tandem trucks with Gross Vehicle Weight (GVW) above five tons. Cilincing motor vehicle testing center conducts vehicle testing every day. The number of vehicles tested is an average of 500 vehicles that can potentially increase air pollution in the working environment of motor vehicle testing center so that workers are at risk of exposure to particulate matter of the emissions of the motor vehicle.

Therefore, this study aimed to analyze the association between diesel particulate matter with elevated HbA1c and Apo-B levels in the blood of workers at Cilincing Motor

Vehicle Testing Centre, Jakarta. In this study, the concentration of diesel particulate matter exposure and individual characteristics, i.e. sex, age, body mass index, and smoking habit were also analyzed as a factor that may contribute to increase HbA1c and Apo-B levels in the blood.

2. Methods

This research is analytical quantitative research conducted to find out the relationship of diesel particulate matter exposure with the increase of HbA1c and Apo-B level in blood at mechanical test officer at Cilincing Motor Vehicle Testing Centre, Jakarta. The respondent with a history of cardiovascular diseases, diabetes diseases and hypertension were excluded. Blood samples for HbA1c test were obtained from 18 mechanics officer and 13 administrative officers, 18 workers for control. These blood samples were analyzed with high-performance liquid chromatography (HPLC) ion changes. Blood samples for Apo B test were obtained from 19 mechanics officer and 14 administrative officers, and 24 workers for control. These samples were analyzed with Polyethyleneglycol (PEG*)* enhanced immunoturbidimetric assay. Both Apo-B and HbA1c were analyzed in standardized Prodia Health Laboratory. Measurement of particulate matter exposure used Leland Legacy Personal Pump and Sioutas cascade impactor produced by SKC Inc. Weighing of sampling filter dust used Mettler Toledo Microbalance done in National Laboratory of Nuclear Energy Agency of Bandung. All of the filters were being conditioned in balance room for 24hr before initial and final weighing. Mean concentration of particulate matters were calculated by the gravimetric method. Questionnaires were used to determine the characteristics of workers, i.e age, sex, BMI, and smoking habits.

3. Results

3.1. Particulate matter (PM) exposure concentration

As shown in table 1, personal exposure concentration of particulate matter was higher in the mechanic officer compared to administrative officers in all particle size. Mean concentration of particulate matter personal exposure on mechanic officers on PM10, PM.2.5, PM1, PM0.5 and PM.0.25 were 342.26 μg/m^3, 232.23 μg/m^3, 190.58 μg/m^3, 164.73 μg/m^3 and 140.10 μg/m^3. While the mean of personal exposure concentration of administration officer on PM10, PM2.5, PM1, PM0.5 and PM0.25 were 208.05 μg/m^3, 168.87 μg/m^3, 149.18 μg/m^3, 128.02 μg/m^3, dan 110.42 μg/m^3.

3.2. HbA1c and Apo-B in mechanic officers, administrative officers, and control group

There were no significant different of mean of HbA1c levels in blood between mechanical test officers (mean = 5.51%), administrative officers (mean = 5.25%) and control groups (mean = 5.38%) with p value = 0.150 (Table 2). Table 2 also shows that there were significant different of mean of Apo B levels (p value = 0.032) in blood of study sample

TABLE 1: Personal exposure concentration of particulate matter measured by the particle size.

Particle Size	Mean (µg/m³)	Median (µg/m³)	Min-Max (µg/m³)	Standar Deviation
Mechanic Officer				
PM_{10}	342.26	270.09	158.86-711.33	153.49
$PM_{2.5}$	232.23	202.02	113.06-520.77	107.45
PM_{1}	190.58	163.02	84.76-484.20	97.56
$PM_{0.5}$	164.73	138.6	68.41-458.39	91.41
$PM_{0.25}$	140.1	117.67	37.90-403.59	83.95
Administrative officer				
PM_{10}	208.05	212.23	131.73-276.03	65.03
$PM_{2.5}$	168.87	171.36	105.98-226.77	65.17
PM_{1}	149.18	149.72	87.46-209.82	64.53
$PM_{0.5}$	128.02	129.42	73.65-179.57	57.7
$PM_{0.25}$	110.42	109.71	61.36-160.88	56

between mechanic officers (mean = 107.63 mg/dL), administrative officers (106.86 mg/dL), and control group (mean = 91.17 mg/dL).

TABLE 2: Mean concentration of Blood markers in the study group.

Blood Marker	Study Group	N	Mean	P-value
HbA1c	Mechanic Officer	18	5.51%	0.15
	Administrative Officer	13	5.25%	
	Control group	18	5.38%	
Apo-B	Mechanic Officer	19	107.63 mg/dL	0.032
	Administrative Officer	14	106.86 mg/dL	
	Control group	24	91.17 mg/dL	

**significant level at p<0.05*

Table 3 shows the correlation between particulate matter in all size and HbA1c. The correlation coefficient value between the particle size and HbA1c and Apo-B levels showed an increasing pattern. The smaller the particle size, the greater the correlation coefficient values. The correlation values between PM10, PM2.5, PM1, PM0.5, PM0.25 and HbA1c levels were 0.464 (p value = 0.052), 0.474 (p value = 0.047), 0.491 (p value = 0.039), 0.502 (p value = 0.034) and 0.505 (p value = 0.033). The correlation values between PM10, PM2.5, PM1, PM0.5, PM0.25 and Apo B levels were 0.022 (p value = 0.929), -0.133 (p value = 0.588), -0.203 (p value = 0.405), -0.306 (p value = 0.203) and -0.314 (p value = 0.191).

Table 3: Correlation between particulate matter exposure and Hba1c level in blood.

Blood Marker	HbA1c		Apo-B	
Particle size	r value	p value	r value	p value
PM_{10}	0.464	0.052	0.022	0.929
$PM_{2.5}$	0.474	0.047	-0.133	0.588
PM_{1}	0.491	0.039	-0.203	0.405
$PM_{0.5}$	0.502	0.034	-0.306	0.203
$PM_{0.25}$	0.505	0.033	-0.314	0.191
*significant level at p<0.05				

3.3. Description of the population studied

3.3.1. Sex.

The statistical test showed that there was a significant difference in mean of HbA1c level in blood of male and female sample (p value = 0.016). The results of statistical analysis found that the mean of HbA1c values in the male sample group (mean = 5.45%) was higher than female sample (mean = 5.10%) (table 4). The mean of Apo B also showed significant differences between male and female (p value = 0.009). It's higher in male (mean = 103.43 mg/dL) than females (mean = 82.63 mg/dL)

3.3.2. Age

There was a significant difference of the mean of HbA1c and Apo B level in sample age above 45 years old and under 45 years old (p value = 0.000 and p value = 0.025) (table 4).

3.3.3. Body mass index (BMI)

There was a significant difference of HbA1c average in the sample with body mass index above 25 kg/ m^2 and sample with body mass index below 25 kg/ m^2 (p value = 0.023). The results of statistical analysis also showed that there was a significant difference of the mean of Apo-B level in the sample group with body mass index above 25 kg/ $m^2$and sample with body mass index below 25 kg/ m^2(p value = 0.0005) (table 4).

3.3.4. Smoking habit

It was found that there was no difference of the mean of HbA1c levels between samples of having a smoking habit and non-smoking habit (p value = 0.183). Meanwhile, there was the difference of the mean of Apo B levels between smoking habit and non-smoking habit sample (p value = 0.022) (table 4)

TABLE 4: Description of population studied.

Variable	Group	N	Mean	Standar Deviation	p-value
HbA1c					
Sex	Male	42	5.45%	0.36	0.016
	Female	7	5.10%	0.2	
Age	≤ 45 years old	12	5.73%	0.39	0.0005
	> 45 years old	37	5.29%	0.28	
Body Mass Index (BMI)	≤ 25kg/m^2	20	5.54%	0.41	0.023
	> 25kg/m^2	29	5.30%	0.3	
Smoking Habit	Yes	26	5.46%	0.4	0.183
	No	23	5.32%	0.31	
Apo-B					
Sex	Male	49	103.43	23.54	0.009
	Female	8	82.63	10.32	
Age	≤ 45 years old	44	111.54	25.205	0.025
	> 45 years old	13	97.25	21.294	
Body Mass Index (BMI)	≤ 25kg/m^2	33	112.08	21.074	0.0005
	> 25kg/m^2	24	92.09	21.33	
Smoking Habit	Yes	30	106.33	23.43	0.022
	No	27	94.04	21.719	

significant level at $p<0.05$

4. Discussion

4.1. Particulate matter (PM) exposure concentration

Particulate matter gathered from the mechanic officer and administrative officer in Cilincing. Every sample was asked to use particulate matter sampling apparatus during their workhours with various duration from 4 to 8 hours a day. Mean concentration of personal particulate matter exposure on both of mechanic officers and administrative officers was very high. This mean concentration was higher than mechanic officers and administrative officers in Pulogadung vehicle testing center done by previous research [14]. The high of concentration personal particulate matter exposure could be caused by different types of vehicles as a source of pollutants.

Cilincing vehicle testing center only tested the specific type of vehicle such as tractor head, dump truck, truck equipped with coupling equipment facility, train patch, train trailer, tank, mixer, crane and CBU tandem truck with Gross Vehicle Weight (GVW) above Five tons. The vehicle was a heavy vehicle, diesel-engined vehicle. These diesel-engined vehicles could be the dominant source of diesel particulate exposure. OSHA (2013) stated that the high average particulate exposure of particulate matter both fine particulate and ultrafine particulate could be caused by a particulate source derived from diesel exhaust. Vehicles are the largest source of pollution of diesel particulate matter. 80 to 95% of inhaled particles of diesel particulate matter are fine particulate (PM2.5) [1, 15]. Particulate exposure is obtained not only from the vehicle that was testing but also from other vehicles that pass around.

Location of Cilincing vehicle testing center is on the edge of the road passing port loading and unloading goods to the port of Tanjung Priok and warehouses complex around. Every day this location is crossed by large and small truck vehicles. Vehicles, trucks and other motor vehicles generate more than half the concentration of ambient air pollution [16]. It can assume that will affect personal particulate matter exposure concentration of mechanic officers and administrative officers. The concentration of ambient particulate matter is strongly associated with personal exposure [17, 18]. Personal particulate matter exposure is higher in people who spend most of the time in open ventilated rooms than people with most of the time in closed-ventilated spaces [18].

4.2. HbA1c and Apo-B in mechanic officers, administrative officers, and control group

Table 2 showed that there was no significant difference of the mean of HbA1c levels in blood between mechanical test officers, administrative officers and control groups (p value = 0.150). This result maybe causes of different of the blood sampling duration with prolonged exposure within just one week. HbA1c levels showed average serum glucose levels for about three months, so short-term exposure to the particulate was not associated with HbA1c. There was no significant association between particulate exposure of PM_{10} and $PM_{2.5}$with an increase in HbA1c within the exposed time range 1 - 7 days before examination [7].

Nevertheless, it could be seen that the mean of HbA1c level in the mechanical test officer (high exposure) was higher than the mean of HbA1c level in the administrative staff (Low Exposure) and the comparison (No Exposure). In this study, it could be assumed that particulate matter exposure was associated with an increase in HbA1c, although it was less visible in short-term exposure. In a previous study conducted on experimental mice subjected to particulate matter, the results showed that particulate matter was associated with elevated HbA1c levels [8]. From some previous studies, particulate matter exposure was associated with elevated HbA1c levels in blood [8-11]. In this study, the association between concentration of weekly exposure of particulate matter and HbA1c levels showed a positive and significant correlation in PM10, PM2.5, PM1, PM0.5 and PM0.25 with elevated HbA1c levels in the blood. The degree of correlation showed that the smaller the dust size, the greater the correlation coefficient and the more significant increase in HbA1c in the blood (Table 3). This research was in line with research conducted in PKB Pulo gadung and PKB Ujung Menteng, finding that PM2.5 personal exposure increased HbA1c levels in the blood of workers [19]. It's also in line with Sade et al. (2016) study, stating that PM10 and PM2.5 were positively correlated with elevated HbA1c levels.

Table 2 also showed that there was a difference of mean (p value = 0.032) that significant Apo-B levels in the blood of study sample from mechanical, administrative, and control group workers. Meanwhile, from the statistic results, it showed that the particle had a negative correlation and it was not significant in PM10, PM2.5, PM.1, PM0.5 and PM0.25 with the increase in Apo B levels (table 3). These results were in contrast to

the results of previous studies. This might be due to a small sample of the study. The previous study found that exposure to particulate matter might cause cardiovascular disorders [6].

Particulate matter exposure can indirectly increase oxidative stress and activate the inflammatory flow. Fan et al. suggests that particulate matter exposure can induce cardiovascular disease indirectly. Long-term exposure of particulate matter may increase the inflammatory process in the blood and indirectly leads to excessive Apo-B production that can increase LDL levels and HDL level [20].

4.3. Description of the population group

4.3.1. Sex

From the statistical test, it showed that there was a significant difference in mean of HbA1c level in blood of male sample and female sample (p value = 0.016). It could be the cause of the job sector of motor vehicle testers was dominated by men. This study was in line with the previous study, stating that sex is associated with elevated levels of HbA1c in the blood [22]. The results of this study were not in line with Simon et al. (1989) study, stating that there was no significant difference in HbA1c increase in men and women [23].

The results of the statistical analysis found that the mean of Apo-B values in the male sample group was higher than the female sample. It's in line with this study, research conducted by Sharma, et al. (2006), in India found that there was a continuous increase in Apo-B levels in line with the increasing age and the male samples that had a significant increase ($p < 0.01$) compared with women. The study concluded that Apo-B levels were significantly influenced by gender and age. Males had a higher risk because Apo-B levels in serum were relatively elevated and Apo-A1 levels were relatively lower compared with females even though mechanism of gender-influencing in Apo-B levels still needed a further explanation [24].

4.3.2. Age

Age was independently associated with elevated hemoglobin in blood [22]. Based on the statistical test, there was a significant difference of the mean of HbA1c level in sample age above 45 years and sample age below 45 years (p = 0.000) (table 4). In this study, age was independently associated with HbA1c in blood. It's in line with the previous study, stating that HbA1c appeared as an independent parameter, influenced only by factors closely related to diabetes i.e. age, obesity and family history of diabetes [23]. The value of Apo-B could also be affected by age, as found by Sharma, et al. (2006), stating that there was a continuous increase in Apo-B levels in line with increasing age and male samples that had a significant increase ($p < 0.01$) compared with women. The study concluded that Apo-B levels were significantly influenced by gender and age.

4.3.3. Body mass index (BMI)

Obesity or overweight can affect levels of HbA1c in blood, with the addition to age and family history of diabetes [23]. Based on the statistical test, there was a significant difference of HbA1c average in the sample with body mass index above 25 kg/ m^2 and sample with body mass index below 25 kg/ m^2 (p value = 0.023). The study was supported by the results of the previous study of healthy individuals with BMI 20 - 44 kg/ m^2, stating that there was a combination with HbA1c elevation [11]. Body mass index independently associated with elevated levels of HbA1c in the blood [22]. The results of statistical analysis also showed that there was a significant difference of the mean of Apo-B level in the sample group with body mass index above 25 kg/ $m^2$and sample with body mass index below 25 kg/ m^2. Groups categorized as overweight experienced an increase in the Apo-B/Apo-A1 ratio and the risk of cardiovascular disease while in the normal weight group, the ratio did not show significant association with cardiovascular risk [25].

4.3.4. Smoking habit

Smoking habits are associated independently with elevated HbA1c levels in the blood [22]. Based on the statistical test, it was found that there was no difference of the mean of HbA1c levels between samples of having a smoking habit and non-smoking sample (p value = 0.183). Although it was found that there was no difference in mean of HbA1c levels in the smoking cohort with no smoking habits, the mean of HbA1c levels in the smoking group was higher than those without smoking habits. The results of this study were in line with previous studies which found that elevated levels of HbA1c in smokers were higher than for non-smokers, both male, and female [23]. Smoking can also lower estrogen levels and further reduce HDL levels. Smoking can increase levels of Apo-B and levels of Apo-B are believed to be associated with early cardiovascular risk. The additional discovery by Brisschetto et al. also found that Apo-B levels in former smokers were almost equal to Apo-B levels in the non-smoker group [26].

5. Conclusion

Both of HbA1c and Apo-B could be considerate as a blood marker for long-exposure of particulate matter. There was a correlation between particulate matter exposure and elevated level of HbA1c in blood samples. Also, there was significantly different at mean concentration Apo-B between the mechanic officer, administrative officer, and the comparison group. Independent variable such as sex, age, BMI, and smoking habit could contribute to increasing Apo-B and HbA1c level in blood.

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Competing Interest

This study was conducted without any competing interest.

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