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Association Between Smoking Habits, Physical Activity, Added Sugar Consumption and Nutritional Status with Malondialdehyde (MDA) and Glucose Levels in Adults

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Abstract: The objective of this study was to analyze the association between smoking habits, physical activity, added sugar consumption and nutritional status with plasma malondialdehyde (MDA) and blood glucose levels in adults. This was a cross-sectional study and a total of 102 adults (47 men and 55 women) participated in this study. Pearson correlation test was used to analyze the correlations between variables in this study. The results showed that most of the participants were smokers (50%), physically inactive people (61.2%), overweight/obese (46.6%) and had high consumption of added sugars (60.2%). More than 30% of participants had high MDA and blood glucose levels. There were significant associations between smoking habits and plasma MDA levels ($p<0.05$, $r = 0.65$); consumption of added sugars and blood glucose levels ($p<0.05$, $r = 0.24$); nutritional status (BMI) and blood glucose levels ($p<0.05$, $r = 0.43$); as well as plasma MDA and blood glucose levels ($p<0.05$, $r = 0.51$) of the participants. There was no significant association between physical activity level and blood glucose levels. This study implied that variabels which were significantly associated with participants' blood glucose levels were nutritional status, consumption of added sugars and plasma MDA levels.

Key words: Adults, consumption, glucose, malondialdehyde

INTRODUCTION

Diabetes mellitus (DM) is one of non-communicable diseases that requires a serious attention in recent years. WHO (2014) reports that 347 million people have diabetes and more than 80% of them are from poor and developing countries. Diabetes prevalence in Indonesia increases almost two-fold, from 1.1% in 2007 to 2.1% in 2013 (Kemenkes, 2014).

Type 2 DM is caused by various factors, namely genetic and environmental factors, lifestyles and dietary pattern. Overweight and lack of physical activity increase the risk of type 2 DM (Klein *et al.*, 2004; Gittelsohn and Rowan, 2011). This disease is also reported to be associated with the high intake of carbohydrates, particularly simple carbohydrates such as sugar (Livesey and Taylor, 2008; Malik *et al.*, 2010; Ambrosini *et al.*, 2013). Exposure to free radicals (pro-oxidant) and low antioxidant also trigger pro-inflammatory state in various cells, thereby increasing the risk of various metabolic diseases, such as type 2 DM (Azam *et al.*, 2003; Kempf *et al.*, 2010). Dietrich *et al.* (2003) stated that smokers had a greater pro-oxidant exposure and lower plasma antioxidant content than non-smokers.

Adult group is one of the groups which is quite vulnerable to type 2 DM. This is caused by lifestyles, namely high sugar consumption, smoking habits and lack of physical activity. The prevalence of overweight adults increased from 13.9% in 2010 to 19.7% in 2013. This was partly due to the high consumption of sugar. Ministry of Health (Kemenkes) in 2014 showed that 50% of Indonesian population consumed sweets at least once a day. The prevalence of cigarette smoking in men aged over 15 years was 64.9% while the prevalence in women was 4.6%.

The general objective of this study was to analyze the association between smoking habits, physical activity, sugar consumption and nutritional status with plasma malondialdehyde (MDA) blood glucose levels. The specific objectives were to: (1) identify the participants' socioeconomic characteristics, smoking habits, physical activity, sugar consumption and nutritional status based on BMI; (2) analyze the association between smoking habits and oxidative status of the participants assessed from plasma MDA levels; (3) analyze the association between physical activity and blood glucose levels of the participants; (4) analyze the association between sugar consumption and blood glucose levels of the participants; (5) analyze the anthropometric-based nutritional status and blood glucose levels of the participants and (6) analyze the association between plasma MDA levels and blood glucose levels of the participants.

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MATERIALS AND METHODS

The design used in this study was cross-sectional. This study was conducted in Pancoran Sub-district, South Jakarta, Special Capital Region of Jakarta. Participants were purposively selected by considering several characteristics, namely socioeconomic, educational level, income, occupation and gender. Participants in this study were adult men and women aged more than 19 years; willing to have their blood taken; not consuming vitamin C, E or antioxidant supplements regularly and not taking any medication that could affect MDA and blood glucose levels at the time of blood sampling. The number of participants in this study was 102 people, consisted of 47 adult men and 55 adult women.

Socioeconomic characteristics: Socioeconomic data (age, education, occupation and income) were asked directly by using a questionnaire.

Smoking habit: Data on smoking habit were acquired by asking directly using a questionnaire. These data included smoking frequency and the number of cigarettes smoked by participants.

Physical activity: Physical activity data were collected using a structured questionnaire by 2 x 24 h activity recall method, in weekdays and weekend (holiday). These data were calculated using physical activity level (PAL) (Mahan and Stump, 2008).

Sugar consumption: Data on sugar consumption were obtained by using a questionnaire, weighing and recording. The data collected were the added sugars consumed in household, as well as the added sugars from snacks and food retails. The added sugars were measured by a digital scale with 0.01 kg accuracy. Meanwhile, the added sugars derived from the food retail were known from the nutrition fact on the packaging.

Malondialdehyde (MDA): Plasma MDA measurement was preceded by venous blood sampling performed by trained health personnel. The blood samples were then analyzed using thiobarbituric acid-reactive substances (TBARS) test by an accredited laboratory. MDA level was considered as high if it was >1.71 (Dixon *et al.*, 1998).

Fasting blood glucose: The measurement of fasting blood glucose (FBG) was preceded by an overnight fasting 8-12 h before the blood sampling. Venous blood sampling was performed by the medical personnel. The blood samples were then analyzed by hexokinase method by an accredited laboratory. A participant was defined as pre-diabetes if the blood glucose level was $\geq$100 mg/dL and diabetes if the level was $\geq$126 mg/dL (IDF, 2013).

Body mass index: Body weight was measured by a digital scale with a capacity of 200 and 0.1 kg accuracy. Height was measured using microtoise with a capacity of 200 and 0.1 cm accuracy. Body mass index (BMI) was calculated using the ratio of body weight (kg) by the square of height (m^2). A participant was categorized as obese if the BMI was $\geq$25 kg/m^2 (Perkeni, 2011).

Waist-hip ratio: Waist-hip ratio (WHR) was calculated by dividing the waist measurement by hip measurement. Waist circumference was measured using a measuring tape with 0.1 cm accuracy. It was measured by wrapping the tape to the navel as the main boundary. Hip circumference was measured at the widest circumference of the buttocks and the measuring tape was parallel to the floor. Obese was defined as WHR $\geq$ 0.9 in men and $\geq$0.85 in women (WHO, 2008).

Statistical analysis: The data were processed and analyzed using descriptive and inferential statistics by 2010 Microsoft Excel and SPSS version 20.0 for Windows. Correlation test used in this study was Pearson test which was performed to analyze the association between smoking habits (frequency and the number of cigarettes smoked), physical activity (PAL), sugar consumption and nutritional status (BMI and WHR) with plasma MDA and blood glucose levels. Comparative test used in this study was independent sample t-test which was performed to analyze the differences in various variables between men and women.

RESULTS

Pancoran Sub-district is one of sub-districts located in South Jakarta. The total number of participants was 102 people aged more than 19 years. Most of them (82.4%) aged between 30-49 years in general. Educational level of men and women was considered as high (87.3%). Most of the participants worked as private employees and most of the women did not work. Participants' income per capita per month ranged between Rp 5,000,000 to Rp 9,900,000 with a mean income of Rp 7,352,451. The distribution of socioeconomic characteristics were shown in Table 1.

Data on smoking habits, physical activity and sugar consumption in this study were collected through interviews. Based on the smoking habits, half of the participants were smokers with a mean number of cigarettes smoked was 10.5±14.9 cigarettes per day. The proportion of smokers in men was greater (53.2%) than women (47.3%). Results of the comparative test showed that men smoked more frequently than women ($p<0.05$). These results were in accordance with the Ministry of Health (2014) stating that smoking frequency in men was greater than women. Smoking habit was more common in men due to environmental factors.

They were influenced by their friends who frequently smoked.

Most of the participants (54.4%) were not used to exercise. The proportion of women not accustomed to exercise was greater (60.0%) than men (48.9%). It could also be identified from PAL in which most of the participants (61.2%) had low PAL.

The proportion of male participants who consumed excessive amount of sugars tended to be greater (70.2%) than female participants (52.7%). Comparative test results showed that there was no significant difference in mean sugar consumption between men and women. This was due to frequent consumption of coffee and tea with added sugars.

Based on BMI, most of the participants (46.6%) had a normal nutritional status. Proportion of overweight or obese participants was also quite large (>40%). Based on WHR, most of the participants (68.0%) were "at risk" category. Comparative test showed that there was a significant difference in mean WHR between men and women ($p<0.05$). Smoking habits, physical activity and sugar consumption could be seen in Table 2.

There were 35% of the participants with high FBG levels. Proportion of male participants with high FBG levels tended to be higher (56%) than female participants (44%). A total of 32% of the participants had high MDA levels. The proportion of men with high MDA levels was smaller (25%) than women (36%). Although differences in proportions tended to happen, the results of comparative test showed that there were no significant differences in mean plasma MDA and blood glucose levels between men and women. Measurement results of FBG status and MDA could be seen in Table 3.

DISCUSSION

The association between oxidative status and smoking habits, either smoking frequency or the average number of cigarettes smoked by the participants per day, were analyzed in this study. Results of Pearson test showed that there was a significant correlation between smoking frequency and MDA levels of the participants ($p<0.05$, $r = 0.652$). High MDA level was a reflection of high pro-oxidant level in the body or the low oxidative status of a person. These results were consistent with the previous studies which showed that smokers had worse oxidative status than non-smokers. Ma *et al*. (2000) stated that a smoker had a lower antioxidant status than non-smoker. Dietrich *et al*. (2003) stated that smokers had a greater pro-oxidant exposure and lower plasma antioxidant content than non-smokers (Table 4).

Results of PAL analysis showed that there was no significant association between the levels of physical activity and blood glucose levels of the participants. This result was different from the previous studies which had reported that physical activity contributed to the prevention of various diseases considered as metabolic syndrome components, including type 2 DM (Klein *et al*., 2004; Bassuk and Manson, 2005; Gittelsohn and Rowan, 2011). The results of this study showed that low physical activity was not always related to high blood glucose levels. WHO (2006) stated that high blood glucose level (DM) was affected by many factors, including genetics, obesity, dietary pattern, physical activity and organ damage. Therefore, it could be concluded from this study that high blood glucose level was more related to other factors, such as high consumption of added sugars and nutritional status (Table 5).

Blood glucose levels of the participants was associated with sugars added during food preparation or presentation and not due to the sugars that were naturally present in food. The analysis on sugar consumption showed that there was a significant association between mean consumption of added sugars and blood glucose levels of the participants ($p<0.05$, $r = 0.242$). Sugar (sucrose) was one of the types of carbohydrates which had high glycemic index (GI). Continuous consumption of the high-GI carbohydrates could increase blood glucose levels and caused insulin resistance (WHO, 2014). The results in this study were consistent with the previous studies. The results of meta-analysis by Malik *et al*. (2010) showed that high sugar consumption from sweet beverages was associated with high blood glucose levels, an indicator of type 2 DM. Ambrosini *et al*. (2013) also revealed that sugar-sweetened beverage consumption also increased the risk of metabolic syndrome in adolescents, such as abnormal blood glucose and blood lipid levels (Table 6).

BMI, classified as obese, is associated with high blood glucose levels (Tobias *et al*., 2014). WHR is also related to diabetes (WHO, 2008). Nutritional status in this study indicated that there was a significant association between blood glucose levels and BMI ($p<0.05$, $r = 0.429$) but it had no significant association with WHR. Overweight/obesity, characterized by high BMI values, is a risk factor of metabolic syndrome components, including diabetes. Mahan and Stump (2008) explain that various products produced by fat accumulation in adipose cells affect the action of insulin in maintaining blood glucose levels to remain normal. Results in this study were in accordance with the previous studies. Various studies had consistently reported that nutritional status was the risk factor of metabolic syndrome components, including type 2 DM (WHO, 2006). According to the study by Adnan *et al*. (2013), higher BMI was significantly associated with high blood glucose levels and the risk of type 2 DM (Table 7).

MDA levels were used to observe how high the levels of free radicals in the body, which was shown by the low activity of antioxidant enzymes and high MDA levels in plasma (Zakaria, 1996; Winarsih, 2011). Results of MDA

Table 1: Distribution of participants based on socioeconomic characteristics

	Gender					
	Men		Women		Total	
Characteristics	n	%	n	%	n	%
Age						
19-29 years	1	2.1	5	9.1	6	5.8
30-49 years	40	85.1	44	80.0	84	82.4
≥50 years	6	12.8	6	10.9	12	11.8
Mean±SD	42.8±6.9		41.0±7.8		41.8±7.4	
Education						
Not in school/primary school graduates	2	4.3	4	7.3	6	5.9
Junior high school/Islamic junior high school graduates	4	8.5	3	5.5	7	6.9
Senior high school/university graduates	41	87.2	48	87.3	89	87.3
Occupation						
Civil servant/SOE	5	10.6	1	1.8	6	5.9
Private employee	30	63.8	2	3.6	32	31.4
Entrepreneur	3	6.4	10	18.2	13	12.7
Laborer	2	4.3	2	3.6	4	3.9
Others	7	12.8	1	6.9	7	6.9
Unemployed	1	2.1	39	39.2	40	39.2
Income (Rp/capita/month)						
<Rp 5,000,000	12	25.5	19	34.5	31	30.4
Rp 5,000,000-9,900,000	23	48.9	25	45.5	48	47.1
Rp 10,000,000-14,900,000	8	17.0	7	12.7	15	14.7
≥Rp 15,000,000	4	8.5	4	7.3	8	7.8
Mean±SD	7,525,532±4,941,328		7,204,545±5,00,3853		7,352,451±4,953,109	

SOE: State-owned enterprise, Rp: Indonesian rupiahs (IDR), SD: Standard deviation

Table 2: Distribution of participants based on smoking habits, physical activity and sugar consumption

	Gender						
	Men		Women		Total		
Characteristics	n	%	n	%	n	%	p-value
Smoking habits							
Yes	25	53.2	26	47.3	51	50.0	
No	22	46.8	29	52.7	51	50.0	
Smoking frequency							
Light (<10 cigarettes/day)	27	57.4	39	70.9	66	64.7	
Heavy (≥10 cigarettes/day)	20	42.6	16	29.1	36	35.3	
Mean±SD	14.4±17.3		7.2±11.6		10.5±14.9		0.014*
Exercise habits							
No	23	48.9	33	60.0	56	54.4	
Yes (<3 times/week)	15	31.9	17	30.9	32	31.1	
Yes (≥3 times/week)	9	19.1	5	9.1	14	13.6	
Physical activity							
Low (1.40≤PAL≤1.69)	30	63.8	33	60.0	63	61.2	
Moderate (1.70≤PAL≤1.99)	7	14.9	16	29.1	23	22.3	
High (PAL>1.99)	10	21.3	6	22.3	16	15.5	
Mean±SD	1.71±0.36		1.68±0.22		1.70±0.29		0.681
Sugar consumption							
Adequate (≤50 g/day)	14	29.8	26	47.3	40	38.8	
Excessive (>50 g/day)	33	70.2	29	52.7	62	60.2	
Mean±SD	98.3±76.0		86.0±68.3		91.7±71.9		0.392
BMI (kg/m^2)							
Underweight (BMI<18.5)	4	8.5	2	3.6	6	5.8	
Normal (18.5≤BMI<25.0)	20	42.6	28	50.9	48	46.6	
Overweight (25.0≤BMI<27.0)	10	21.3	10	18.2	20	19.4	
Obese (≥27.0)	13	27.7	15	27.3	28	27.2	
Mean±SD	24.2±4.3		25.0±4.3		24.6±4.3		0.306
WHR							
Normal (men: <0.9, women: <0.85)	14	29.8	19	34.5	33	32.0	
At risk (men: ≥0.9, women: ≥0.85)	33	70.2	36	65.5	69	68.0	
Mean±SD	0.93±0.07		0.87±0.07		0.90±0.08		0.000

*Significant at α < 5%, BMI: Body mass index, WHR: Waist-hip ratio

Table 3: Distribution of participants based on blood glucose and plasma MDA levels

	Gender						
	Men		Women		Total		
Blood glucose levels and MDA levels	n	%	n	%	n	%	p-value
Blood glucose levels							
Normal (<100 mg/dL)	27	57	39	71	66	100	
High (≥100 mg/dL)	20	43	16	29	36	100	
Mean±SD	103.1±34.9		110.5±52.7		107.1±45.3		0.418
Oxidative status (plasma MDA)							
Normal (MDA≤1.71)	35	75	35	64	70	100	
High (MDA>1.71)	12	25	20	36	32	100	
Mean±SD	1.06±0.65		1.03±0.69		1.04±0.67		0.786

Table 4: Results of pearson correlation test between smoking frequency and MDA levels of the participants

	MDA						
	Normal		High		Total		
Smoking frequency	n	%	n	%	n	%	p-value
Light (<10 cigarettes/day)	58	87.9	8	12.1	66	100	
Heavy (≥10 cigarettes/day)	12	33.3	24	66.7	36	100	
Mean±SD	6.2±13.1		20.0±14.31		10.5±14.9		0.000*

*Significant at α < 5%

Table 5: Results of pearson correlation test between the levels of physical activity and blood glucose of the participants

	Blood glucose levels						
	Normal		High		Total		
PAL	n	%	n	%	n	%	p-value
Low/moderate (≤1.7)	57	66.3	29	33.7	86	100	
High (PAL>1.7)	9	56.3	7	43.8	16	100	
Mean±SD	1.68±0.25		1.72±0.36		1.70±0.29		0.917

*Significant at α < 5%

Table 6: Results of pearson correlation test between sugar consumption and blood glucose levels of the participants

	Blood glucose levels						
	Normal		High		Total		
Sugar consumption	n	%	n	%	n	%	p-value
Adequate (≤50 g/day)	30	75.0	10	25.0	40	100	
Excessive (>50 g/day)	36	58.1	26	41.9	62	100	
Mean±SD	73.9±49.7		124.3±92.9		91.7±71.9		0.014*

*Significant at α < 5%

Table 7: Results of Pearson correlation test between nutritional status and blood glucose levels of the participants

	Blood glucose levels						
	Normal		Tinggi		Total		
BMI (kg/m^2)	n	%	n	%	N	%	p-value
Normal (BMI<25)	47	87.0	7	13.0	54	100	
Overweight (BMI≥25)	19	39.6	29	60.4	48	100	
Mean±SD	22.9±3.7		27.9±3.5		24.6±4.3		0.000*
WHR							
Normal (men: <0.9, women: <0.85)	27	81.8	6	18.2	33	100	
At risk (men: ≥0.9, women: ≥0.85)	39	56.5	30	43.5	69	100	
Mean±SD	0.89±0.77		0.92±0.08		0.90±0.08		0.430

*Significant at α < 5%, BMI: Body mass index, WHR: Waist-hip ratio

analysis indicated that there was a significant association between MDA levels and blood glucose levels of the participants (p<0.05, r = 0.505). These results showed that the higher the MDA levels of the participants, the higher the blood glucose levels. Various studies on oxidative status had been carried out and some of them had associated it with the risk of type 2 DM. High pro-oxidant levels in human body lead to the decreased function of insulin and its receptors in the cells. Therefore, glucose cannot be converted into energy. This condition causes the blood glucose levels to remain high and it will increase the risk of type 2 DM (Park, 2006; Dewi, 2007). In accordance with the finding, Kempf *et al.* (2010) revealed that the high antioxidants in

Table 8: Results of pearson correlation test between MDA and blood glucose levels of the participants

	Blood glucose levels						
	Normal		High		Total		
MDA	n	%	n	%	N	%	p-value
Normal (MDA≤1.71)	58	82.9	12	17.1	70	100	
High (MDA>171)	8	25.0	24	75.0	32	100	
Mean±SD	0.66±0.48		1.75±0.25		1.04±0.67		0.000*

*Significant at α < 5%

food and beverages could prevent cell inflammation; thus, lowering the risk of metabolic syndrome, including type 2 DM (Table 8).

Conclusion and recommendation: Most of the participants in this study were overweight/obese and light-frequency smokers. Most of them did not exercise regularly, had low PAL and consumed sugars above the limits recommended by the guideline of balanced nutrition. There was a significant association between smoking habits and oxidative status of the participants, as seen from plasma MDA levels. There was no significant association between physical activity and blood glucose levels of the participants. There was a significant association between sugar consumption and blood glucose levels of the participants. There was a significant association between blood glucose levels and BMI-based nutritional status, but not with WHR-based nutritional status. There was a significant association between MDA and blood glucose levels of the participants. Variables associated with blood glucose levels of the participants were BMI, smoking habits, sugar consumption and plasma MDA levels. Further study is needed to analyze the causal effects of various variables on blood glucose levels.

Healthy lifestyles, such as not smoking; doing regular exercise and reducing sugar consumption, need to be implemented by the community. They are needed, especially for the adult group, in order to maintain blood glucose levels to remain normal. This was a cross-sectional study; thus, further studies need to be conducted to analyze the causal relationship between blood glucose levels and various related aspects.

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