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Unhealthy food pattern, physical activity, and the incidence of diabetes mellitus among adults with central obesity

Pola makan berisiko, aktivitas fisik, dan kejadian diabetes melitus pada dewasa obesitas sentral

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Abstract

The prevalence of diabetes mellitus (DM) in Indonesia is increasing. A significant risk factor for developing DM is central obesity. Lifestyles, including diet and physical activity, strongly influence the high prevalence of DM and obesity. The study aimed to analyze the association between unhealthy food consumption and physical activity among adults with central obesity in Indonesia. This study used secondary data from Riskesdas 2018 with a cross-sectional design. The subjects in this study were adults (≥ 19 years old) with central obesity. A total of 7493 subjects were included in the analysis. Food intake data were taken using a validated FFQ, and physical activity using the GPAQ questionnaire. The data were analyzed using a chi-square test and multiple logistic regression. Frequent consumption of sweet foods (p=0,001, OR=1,235), sweetened beverages (p=0,042, OR=1,157), carbonated drinks (p=0,001, OR=1,324), instant noodles (p<0,001, OR=1,845), salty foods (p<0,001, OR=1,669), seasoning (p<0,001, OR=1,514), processed meats (p=0,009, OR=1,199), fatty foods (p<0,001, OR=1,687), and grilled foods (p<0,001, OR=1,243) were positively associated with the incidence of DM among adults with central obesity after adjusted with confounding variables. Low physical activity increased the incidence of DM among adults with central obesity in the unadjusted model (p=1,161, OR=1,161). In conclusion, there is a relationship between the consumption of unhealthy foods and physical activity with the incidence of DM in Indonesian adults with central obesity.

Keywords: Diabetes mellitus, central obesity, physical activity, unhealthy foods

Abstrak

Prevalensi diabetes melitus (DM) di Indonesia terus meningkat. Salah satu faktor risiko utama dari kejadian DM adalah obesitas sentral. Tingginya prevalensi DM dan obesitas sentral sangat dipengaruhi oleh gaya hidup berupa pola makan dan aktivitas fisik. Penelitian bertujuan untuk menganalisis hubungan konsumsi makanan berisiko dan aktivitas fisik dengan kejadian diabetes melitus pada dewasa obesitas sentral di Indonesia. Penelitian ini menganalisis data sekunder Riskesdas 2018 dengan desain *cross sectional*. Sampel yang digunakan ialah dewasa ≥19 tahun dengan obesitas sentral sebanyak 7493 orang. Data asupan makanan diambil menggunakan FFQ tervalidasi dan aktivitas fisik menggunakan kuisioner GPAQ. Data dianalisis menggunakan uji chi square dan regresi logistik berganda. Sering mengonsumsi makanan manis (p=0,001, OR=1,235), minuman manis (p=0,042, OR=1,157), minuman berkarbonasi (p=0,001, OR=1,324), mie instan (p<0,001, OR=1,845,), makanan asin (p<0,001, OR=1,669), bumbu penyedap (p<0,001, OR=1,514), daging olahan berpengawet (p=0,009, OR=1,199), makanan berlemak (p<0,001, OR=1,687), dan makanan dibakar (p<0,001,

OR=1,243) berhubungan positif dengan peningkatan kejadian DM pada dewasa obesitas sentral setelah dikontrol dengan variabel perancu. Kurang aktivitas fisik berhubungan signifikan terhadap peningkatan kejadian DM pada dewasa obesitas sentral pada model sebelum dikontrol dengan variabel perancu (p=1,161, OR=1,161). Terdapat hubungan antara sebagian besar konsumsi makanan berisiko dan aktivitas fisik dengan kejadian DM pada dewasa obesitas sentral di Indonesia.
Kata Kunci: Aktivitas fisik, diabetes melitus, makanan berisiko, obesitas sentral

Introduction

Degenerative diseases are one of the largest diseases in the world and are the highest cause of death, accounting for 71% of total deaths in the world (WHO, 2018). One of the degenerative diseases that often affect the community is diabetes mellitus. Indonesia is one of the countries with the largest number of diabetics, ranking fifth in the world after China, India, Pakistan, and the United States (International Diabetes Federation, 2021). Based on data from Basic Health Research in Indonesia, the prevalence of diabetes mellitus according to the results of blood sugar levels increased from 6,9% in 2013 to 8,5% in 2018 (Balitbangkes RI, 2019). The prevalence of diabetes also increases with age. This is because increasing age can affect the decline in metabolism and physiology of the body, especially the function of pancreatic beta cells in the endocrine system (Brown et al., 2017).

There are several risk factors for diabetes mellitus, namely genetic, sociodemographic, and lifestyle factors (Idris et al., 2017). One of the main risk factors for diabetes is lifestyle factors in the form of central obesity (Herlina et al., 2020). The prevalence of central obesity in Indonesia has increased from 26,6% in 2013 to 31% in 2018 (Balitbangkes RI, 2019). Previous research revealed that central obesity has a significant influence on the incidence of diabetes mellitus in the Indonesian population aged >15 years (Rewasan et al., 2022). It is known that respondents with central obesity have an 8,3 times higher risk of developing type 2 diabetes mellitus compared to respondents without central obesity (Sari, 2018). Individuals with central obesity are more at risk of developing diabetes mellitus because there is a buildup of visceral and subcutaneous abdominal fat tissue that can produce excess free fatty acids (free fatty acids), resulting in insulin resistance (De Mutsert et al., 2018). If not treated immediately, the incidence of diabetes mellitus in adults with central obesity can have an impact on other diseases such as metabolic syndrome, cardiovascular disease, and death (Palmer & Toth, 2019).

The high prevalence of diabetes mellitus and central obesity in Indonesia is strongly influenced by lifestyles such as unhealthy food consumption and sedentary behavior or low physical activity. An unhealthy diet is often described as a western diet with characteristics high in calories, sugar, saturated fat, sodium, and fiber. The diet is known to have a positive relationship with increasing metabolic syndrome components such as blood sugar levels, abdominal circumference, triglycerides, and blood pressure (Rodrguez-Monforte et al., 2017). In Indonesia, unhealthy eating patterns are described as the consumption of risky foods. Risky foods are foods or drinks that, if consumed in excess, can pose a risk of degenerative disease events (Balitbangkes RI, 2019). The mechanism of increasing the risk of diabetes mellitus due to consumption of risky foods can occur through various things such as increased blood sugar levels, insulin resistance, inflammation, weight gain, abdominal circumference, and impaired insulin secretion (Rodrguez-Monforte et al., 2017).

Healthy diets such as the DASH diet and the Mediterranean diet are characterized by being rich in fruits, whole grains, cereals, and marine animals that are high in fiber, vitamins, minerals, and saturated fat (Medina-Remón et al., 2018). Various studies show that this diet can prevent the incidence of central obesity, diabetes mellitus, and metabolic syndrome (Agodi et al., 2018; Medina-Remón et al., 2018; Rodrguez-Monforte et al., 2017). The consumption of vegetables and fruits by the Indonesian population is known to be low (Hermina & S., 2016). Lack of consumption of vegetables and fruits is associated with 2,91 times the risk of developing diabetes mellitus

compared to respondents with sufficient consumption of vegetables and fruits (Kistianita et al., 2018). Sedentary lifestyles and low physical activity are also contributing factors to the increasing prevalence of diabetes mellitus and central obesity. Advances in technology encourage a person to behave sedentarily and have low physical activity. Previous research revealed that individuals with less physical activity had a 3,2-times higher risk of suffering from diabetes mellitus (Al Rahmad, 2021; Herlina et al., 2020).

Research on consumption behavior and physical activity in adults with central obesity at the national level is still rare, so researchers are interested in conducting studies related to lifestyle and central obesity. Based on this background, this study aims to analyze the relationship between consumption of risky foods and physical activity and the incidence of diabetes mellitus in centrally obese adults in Indonesia based on basic health research 2018 data.

Methods

The study used a cross-sectional design. The population used in this study was all adults in Indonesia who were sampled by National Health Survey (NHS or RISKESDAS) in 2018 and underwent blood tests. In RISKESDAS 2018, individuals who had undergone blood tests were 19,418 households from 2,498 census blocks in 26 provinces. The selection of census blocks was carried out using the PPS (probability proportional to size) method using the multistage systematic random sampling method (Balitbangkes RI, 2019).

The sample used in this study is the total of all individuals selected in the 2018 Riskesdas Census Block (CB) who meet the inclusion and exclusion criteria. The inclusion criteria of this study are individuals aged ≥ 19 years with an abdominal circumference of 90 cm in men and 80 cm in women, having fasting blood glucose (FBG) or blood sugar 2 hours postprandial (BS2HPP) specimen data, having complete data on subject characteristics (age, sex, education, place of residence), smoking habits, consumption of alcoholic beverages, consumption of risky foods, consumption of fruit and vegetables, and physical activity. The criteria for exclusion from the study were subjects using anti-diabetic drugs or insulin injections. The number of subjects receiving data was 34,968, and among them were as many as 12,837 subjects with missing data. Furthermore, 22,131 subjects were screened again based on inclusion and exclusion criteria. As a final result, 7493 subjects were analyzed in this study. This study used the Riskesdas survey code of ethics obtained from the Health Research Ethics Commission of the Indonesian Ministry of Health (LB.02.01/2/KE.267/2017).

The data in this study is secondary data from Riskesdas data in 2018 from the Health Development Policy Agency. All data is retrieved by trained enumerators from the Riskesdas team. The respondents used in this study were adults with central obesity. Based on the criteria of the International Diabetes Federation (IDF), central obesity in South and East Asians is determined if respondents have an abdominal circumference of 90 cm in men and 80 cm in women. Anthropometric measurements of abdominal circumference are carried out by measuring the midpoint between the last rib cage and the top of the pelvic bone in an upright standing position using a 1 mm accuracy tape meter (Balitbangkes RI, 2019). The dependent variable in this study was the incidence of diabetes mellitus. Based on the American Diabetes Association (ADA) and PERKENI, respondents are said to have diabetes mellitus if they have FBG levels of 126 mg/dL and/or GD2PP levels of 200 mg/dL (International Diabetes Federation, 2021; PERKENI, 2019). Blood sugar checks were carried out at the research site using the Accuchek Performance Tool (Balitbangkes RI, 2019).

Risk food intake data is obtained from the results of the validated FFQ questionnaire (Balitbangkes RI, 2019). The answer choices regarding the frequency of consumption of risky foods in the past month consisted of >1 x/day, 1 x/day, 1-2 x/week, 3-6 x/week, 3 x/mo, and never. Then categorized into two categories: often (1 x/day or 1-6 x/week) and rarely (3 x/month or never) (Milita et al., 2021). Risk foods consist of sweet foods, sugary drinks, soft drinks and carbonated drinks, instant noodles and other instant foods, salty foods, seasonings, meat, chicken, and processed fish foods with preservatives, fatty and cholesterol-rich foods, fried foods, burned foods, and energy drinks.

Sweet foods are foods that contain high amounts of sugar, such as dodol, chocolate, candy, cake, canned fruit, traditional sweet cakes, etc. Sugary drinks are high-sugar drinks such as syrups, packaged sweet teas, drinks with added sugar, and other packaged sweet drinks that are not fizzy. Salty foods are foods that are more dominant in salty taste or contain high salt content, such as salted fish, pindang fish, salted eggs, and salty snacks. Fatty foods are animal and plant foods that contain high levels of saturated fat and cholesterol. Burned food is food that is processed by burning directly on a fire, such as satay, grilled chicken, goat roll, grilled fish, and other animal foods that are burned using charcoal or other ingredients. Preservative-processed foods are animal foods that go through the processing process with added preservatives, such as corned beef, sausages, burger meat, and smoked meats. Energy drinks are drinks that contain caffeine as an energy source. Instant food is food that can be served quickly and contains high sodium, such as instant noodles, instant porridge, and other instant foods (Balitbangkes RI, 2019).

Physical activity was measured using the Global Physical Activity Questionnaire (GPAQ), which includes vigorous and moderate physical activity activities at daily activities (combined at work or home, leisure, and travel) in the number of days per week and the number of minutes per day. Then it is converted into units of METs per minute per week. Respondents are said to have sufficient physical activity if they have a value of 600 METs/minute/week and less if they have 600 METs/minute/week (WHO, 2012). Demographic and lifestyle data in the form of age, gender, education, place of residence, smoking habits, and alcohol consumption were obtained from structured and validated individual questionnaires (Balitbangkes RI, 2019). The level of education is categorized into two categories: high (graduated from high school, dilploma, or PT) and low (not yet graduated from high school and below). Smoking habits during the past month are categorized into yes (smoking daily or occasionally) and no (no smoking at all or former smokers). Consumption of alcoholic beverages is categorized into yes (consuming alcoholic beverages in the past month) and no (Balitbangkes RI, 2019).

The data was analyzed using SPSS software version 25,0. Subject characteristics are presented in mean and standard revisions for numerical variables, as well as frequency and percentage for categorical variables. Bivariate analysis uses the chi-square test to determine the relationship between the independent variable and the dependent variable. Multivariate analysis uses multiple logistic regression analysis with a 95% confidence interval to find the odds ratio (OR). In this study, two models were used, namely unadjusted and adjusted. Model 1 unadjusted was conducted on the dependent variable (diabetes mellitus) and the independent variable (consumption of risky foods, fruit and vegetables, and physical activity). In model 2, confounding variables were added in the form of age, gender, education, place of residence, smoking habits, and consumption of alcoholic beverages. The level of meaning used is 95% CI.

Result and Discussion

A total of 7493 subjects with central obesity were included in this study, and it is known that 1793 of them (23,9%) had diabetes mellitus. The prevalence of DM in centrally obese adults by age and sex is described in figure 1. Based on these figures, it is known that the prevalence of DM increases with age. In all age categories, the prevalence of DM is greater in women than men, except at the age of 40–59, where it is almost the same. There is a significant difference between the prevalence of women and men in the age groups of 40–59 years and 60 years. The highest prevalence of DM was in women aged 60 years (31,5%).

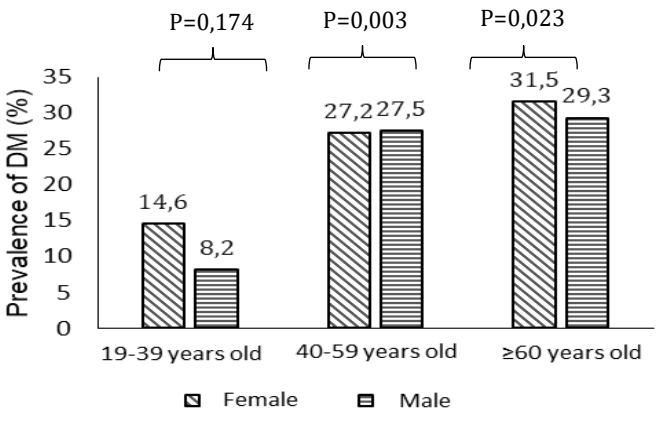

Figure 1. Prevalence of DM in central obese adults by age and sex

The characteristics of the research subject are presented in Table 1. Most of the study subjects were female (82,6%), lived in urban areas (56,8%), had low education levels (69,2%), had non-smoking habits (90,1%), and did not consume alcohol (99,1%). Based on table 2, it is known that the incidence of diabetes mellitus is higher in subjects who often consume sweet foods (78,4%), sweet drinks (82,3%), instant noodles (50,8%), salty foods (71,6%), seasonings (91%), fatty foods (88,6%), and adequate physical activity (80,4%). The risky foods that are rarely consumed are carbonated drinks (93,3%), processed meat preservatives (79,5%), burned foods (70,2%), and energy drinks (96,3%).

Odd ratio values and significance in unadjusted and adjusted models are shown in Table 2. The results showed that there was a significant relationship between frequent consumption of sweet foods (OR = 1,186, 95%CI: 1,044–1,347), sugary drinks (OR = 1,161, 95%CI: 1,012–1,332), instant noodles (OR = 1,471, 95%CI: 1,323–1,637), salty foods (OR = 1,605, 95%CI: 1,430–1,801), seasonings (OR = 1,393, 95%CI: 1,164–1,668), fatty foods (OR = 1,561, 95%CI: 1,329–1,834), baked goods (OR = 1,148, 95%CI: 1,021–1,329), and lack of physical activity (OR = 1,161, 95%CI: 1,014–1,329) with the incidence of diabetes mellitus in central obese adults in the unad This relationship was further strengthened in the adjusted model, except for the physical activity variable, which became insignificant at p > 0,05 (p = 0,830). This shows that confounding variables have a stronger relationship with physical activity. In addition, the variable consumption of carbonated beverages and preservative-processed meat became significant (p 0,05) in the adjusted model. This shows that frequent consumption of carbonated drinks and processed meats will be significantly related if accompanied by older age, women, living in urban areas, low education levels, consuming cigarettes, and consuming alcohol. Energy drink consumption did not have a significant relationship with this study.

This study shows that there is a significant relationship between the consumption of risky foods and the incidence of diabetes mellitus in centrally obese adults. These risky foods are sweet foods, sweet drinks, carbonated drinks, instant noodles, salty foods, seasonings, preservative-processed meats, fatty foods, and burned foods. Lack of physical activity was only significantly associated with the model before it was controlled for confounding variables.

Table 1. Characteristics of the research subject

Variable	Total (n= 7493)
Age (years)	46,95±12,686
Gender	
Female	6192 (82,6)
Male	1301 (17,4)
Residence	
Urban	4257 (56,8)
Rural	3236 (43,2)
Education	
Low	5187 (69,2)
High	2306 (30,8)
Smoking Habits	
Smoke	743 (9,9)
No Smoking	6750 (90,1)
Consumption of Alcoholic Beverages	
Yes	65 (0,9)
No	7428 (99,1)

Relationship of Risk Food Consumption with DM Incidence in Central Obesity

Sweet foods, sugary drinks, and carbonated drinks are characterized as foods that are high in sugar. WHO recommends sugar consumption of no more than 10% of total energy intake, or equivalent to 50 g/day (WHO, 2015). Excessive consumption of sugary foods and drinks is known to increase the risk

of insulin resistance, central obesity, and metabolic syndrome. This is because sweet foods and drinks tend to contain a high glycemic index and load, so they can increase blood glucose levels quickly (Rodrguez-Monforte et al., 2017; Syauqy et al., 2018; Yin et al., 2020). A high glycemic load can exacerbate inflammation and insulin resistance through the release of pro-inflammatory cytokines in response to hyperglycemia (Medina-Remón et al., 2018).

In addition, sugary and carbonated drinks tend to be high in energy but low in micronutrients such as vitamins and minerals (Malik & Hu, 2019). The sweetener commonly used is high-fructose corn syrup (HCFS), which can increase the risk of metabolic syndrome, especially increased insulin resistance, weight gain, and abdominal circumference (Narain et al., 2017; Shin et al., 2018; Sundborn et al., 2019). Excess fructose consumption results in increased lipogenesis and decreased endothelial nitric oxide bioavailability, leading to insulin resistance (Malik & Hu, 2019).

High-sodium foods in the form of salty foods, seasonings, and instant foods are known to be associated with the incidence of diabetes in this study. Previous studies revealed that 53,7% of the Indonesian population consumes salt >5 grams/day, where the average salt intake is 6,68 grams/day, with the largest contribution coming from cooking spices (Atmarita et al., 2016). High consumption of sodium >2000 mg is associated with the incidence of hypertension, insulin resistance, dyslipidemia, and decreased levels of adiponectin in the bloodstream (Baudrand et al., 2014).

The mechanism that leads to the incidence of diabetes mellitus is not yet fully understood, but it is often associated with the incidence of obesity, which is strongly associated with insulin resistance. Consumption of foods high in salt can induce leptin resistance and stimulate thirst and a high appetite. This results in excessive energy intake, leading to obesity and insulin resistance (Y. M. Kim et al., 2018; Lanaspa et al., 2018). In addition, the relationship between instant noodle consumption and blood glucose levels is also associated with the high content of simple carbohydrates, high glycemic load, and low fiber in instant noodles (Huh et al., 2017). This study is in line with previous research, which states that consumption of instant noodles 2x/week is associated with an increased risk of diabetes by 2.1 times compared to consumption of <2x/week (Yogal et al., 2022).

The association between frequent consumption of preservative-processed meat and the incidence of diabetes in centrally obese adults was seen when it was controlled for confounding variables. The results of this study are in line with research in Korea, which revealed that consumption of processed meat by one serving (50 gr) for >3x/week has a prevalence of hyperglycemia 32% greater than consumption rarely after controlling for confounding variables (Y. Kim & Je, 2018). Processed meat contains nitrates as meat preservatives, which in the body can be converted into nitrosamines. It is known that nitrosamines can be toxic to pancreatic cells, resulting in insulin resistance. In addition, people who consume processed meat in excess experience inflammation and high levels of C-reactive protein, which can increase the risk of metabolic syndrome (Abete et al., 2014).

Table 2. Intake and physical activity on the incidence of diabetes mellitus

Variable	Diabetes Melitus		p-value *	Total (n= 7493)
	Yes (%)	No (%)		
Confectionery				
Often	1405 (78,4)	4294 (75,3)	0,009	5699 (76,1)
Infrequently	388 (21,6)	1406 (24,7)		1794 (23,9)
Sugary Drinks				
Sering	1475 (82,3)	4559 (80)	0,033	6034 (80,5)
Jarang	318 (17,7)	1141 (20)		1459 (19,5)
Soft Drink / Carbonated Drinks				
Often	121 (6,7)	336 (5,9)	0,188	457 (6,1)
Infrequently	1672 (93,3)	5364 (94,1)		7036 (93,9)
Instant Noodle/ Other Instant Food				
Often	910 (50,8)	2348 (41,2)	<0,001	3258 (43,5)
Infrequently	883 (49,2)	3352 (58,8)		4235 (56,5)

Variable	Diabetes Melitus		p-value *	Total (n= 7493)
	Yes (%)	No (%)		
Salty Food				
Often	1283 (71,6)	3480 (61,1)	<0,001	4763 (63,6)
Infrequently	510 (28,4)	2220 (38,9)		2730 (36,4)
Seasoning				
Often	1631 (91)	5007 (87,8)	<0,001	6638 (88,6)
Infrequently	162 (9)	693 (12,2)		855 (11,4)
Preservative Processed Meat				
Often	368 (20,5)	1128 (19,8)	0,497	1496 (20)
Infrequently	1425 (79,5)	4572 (80,2)		5997 (80)
Fatty/ Cholesterol/ Fried Foods				
Often	1588 (88,6)	4744 (83,2)	<0,001	6332 (84,5)
Infrequently	205 (11,4)	956 (16,8)		1161 (15,5)
Grilled Food				
Often	534 (29,8)	1538 (27)	0,021	2072 (27,7)
Infrequently	1259 (70,2)	4162 (73)		5421 (72,3)
Energy Drinks				
Often	66 (3,7)	182 (3,2)	0,314	248 (3,3)
Infrequently	1727 (96,3)	5518 (96,8)		7245 (96,7)
Physical Activity				
Less	352 (19,6)	991 (17,4)	0,031	1343 (17,9)
Enough	1441 (80,4)	4709 (82,6)		6150 (82,1)

* Chi Square Test

Fatty foods are foods that are high in fat, including saturated fat and cholesterol. WHO recommends saturated fat consumption in adults, which is <10% of total energy. Excessive consumption of foods high in saturated fat is known to be associated with an increased risk of metabolic syndrome, characterized by impaired glucose homeostasis, increased serum glucose, blood pressure, and triglyceride values (Hosseinpour-Niazi et al., 2015; Julibert et al., 2019). A study shows that excessive consumption of SFA can cause inflammation and insulin resistance in muscles (Kennedy et al., 2009). In addition, this relationship is closely related to the incidence of central obesity, which leads to diabetes mellitus. Epidemiological research shows that excessive consumption of fried foods contributes to weight gain and central obesity (Sayon-Orea et al., 2014).

Tabel 1. Odd Ratio (95% CI) of Diabetes Mellitus incidence related to consumption of risky food, fruit vegetable, and physical activity

Variable	Type 1[a]			Type 2[b]		
	OR	95% CI	p-value	OR	95% CI	p-value
Confectionery						
Often	1			1		
Infrequently	1,186	1,044 – 1,347	0,009	1,235	1,085 – 1,406	0,001
Sugary Drinks						
Often	1			1		
Infrequently	1,161	1,012 – 1,332	0,033	1,157	1,006 – 1,330	0,042
Soft Drink / Carbonated Drinks						
Often	1			1		
Infrequently	1,155	0,932 – 1,432	0,188	1,324	1,063 – 1,650	0,012
Instant Noodle/ Other Instant Food						
Often	1			1		
Infrequently	1,471	1,323 – 1,637	<0,001	1,845	1,647 – 2,066	<0,001

Salty Food						
Often	1			1		
Infrequently	1,605	1,430 – 1,801	<0,001	1,669	1,483 – 1,878	<0,001
Seasoning						
Often	1			1		
Infrequently	1,393	1,164 – 1,668	<0,001	1,514	1,260 – 1,820	<0,001
Preservative Processed Meat						
Often	1			1		
Infrequently	1,047	0,917 – 1,194	0,497	1,199	1,047 – 1,372	0,009
Fatty/ Cholesterol/ Fried Foods						
Often	1			1		
Infrequently	1,561	1,329 – 1,834	<0,001	1,687	1,415 – 1,965	<0,001
Grilled Food						
Often	1			1		
Infrequently	1,148	1,021 – 1,290	0,021	1,243	1,103 – 1,401	<0,001
Energy Drinks						
Often	1			1		
Infrequently	1,159	0,870 – 1,543	0,314	1,260	0,939 – 1,690	0,123
Physical Activity						
Less	1			1		
Enough	1,161	1,014 – 1,329	0,031	1,016	0,882 – 1,169	0,830

[a]*Unadjusted* without being controlled with confounding variables. [b]*Adjusted* was controlled with confounding variables such as age, gender, place of residence, education, smoking habits, and consumption of alcoholic beverages.

In Indonesia, fried foods are usually cooked with high-temperature oil using deep-frying techniques. Heating oil to high temperatures and repeated use of oil are known to cause the formation of advanced glycation end-products (AGEs) and trans fatty acids, increase saturated fatty acids, and reduce the content of cis-unsaturated fatty acids (Bhardwaj et al., 2016; Gulati & Misra, 2017). Consumption of foods containing trans fatty acids is known to decrease insulin sensitivity, increase insulin resistance, and increase belly fat. This is because trans fatty acids can increase proinflammatory cytokines such as TNF and IL-6 and cause high CRP (Bhopal et al., 2017). Similar to fried foods, these adverse effects also occur in burned foods that use high temperatures in the processing process (Zhao et al., 2020). In addition, combustion residues result in food being contaminated by free radicals that can damage pancreatic cell membranes. These results are in line with previous research showing that consuming foods burned >3 times per week increases the risk of metabolic syndrome by 2.6 times (Jusuf, 2020).

Association of Physical Activity with the Incidence of DM in Central Obesity

This study also showed that a lack of physical activity was associated with an increased incidence of diabetes mellitus in the unadjusted model. In line with this study, previous cross-sectional studies have also shown that there is a relationship between low physical activity and increased blood glucose levels (Powell et al., 2018; Suliga et al., 2018). Another study stated that in obese subjects with low physical activity, the risk of increased GDP was 1,66 times greater (Suliga et al., 2018). WHO recommends physical activity in adults for 150–300 minutes per week with moderate intensity or 75–150 minutes with heavy intensity, equivalent to >600 METs per minute per week (WHO, 2020). The results of this study showed that the majority of study subjects had sufficient physical activity, where moderate physical activity contributed more than heavy physical activity according to the adequacy of METs per minute per week. Based on the area of residence, rural communities have a longer average of physical activity than urban communities. As for gender, overall, men have greater physical activity than women. Men are known to be more likely to do heavy physical activity, while women are more likely to do moderate physical activity.

Previous studies have revealed that obese adults who regularly engage in physical activity have been shown to have a better metabolic

profile (Slagter et al., 2018). Physical activity is needed to maintain energy balance in the body so that there is no accumulation of fat cells (Milita et al., 2021). Low physical activity causes calorie burning and body metabolism to not be optimal, causing fat accumulation and obesity. In people with obesity, greater insulin secretion is needed to transport incoming glucose. This condition is called hyperinsulinemia, which then becomes a direct cause of type 2 DM. This is because tissues that are sensitive to insulin become insensitive and produce intrinsic insulin resistance (Eaton & Eaton, 2017).

To the best of our knowledge, this is the first study in Indonesia to discuss the relationship between consumption of various types of risky foods and physical activity and the incidence of diabetes mellitus in centrally obese adults. This study had a large sample, and the analysis considered confounding variables such as age, sex, education, place of residence, smoking habits, and consumption of alcoholic beverages. Apart from these advantages, this study also has some limitations. First, intake data collection only uses FFQ questionnaires and cannot be measured quantitatively, so the data obtained is susceptible to bias and cannot be analyzed in depth. Second, this study did not involve other confounding variables such as percent body fat, comorbidities, or stress levels due to limited data requests. Third, the research design used is a cross-sectional design, so it is difficult to know the causal mechanism accurately, and the results of the relationship must be interpreted carefully.

The integration of nutritional materials in a sustainable manner and examples of complementary foods are key to success in increasing food consumption diversity (Abdillah et al., 2020). An increase in the types of food provided by mothers is also indirectly related to mothers as domestic workers who have a lot of time to pay attention to the food that toddlers must consume (Nasrul et al., 2022).

Conclusion

There is a significant relationship between frequent consumption of sweet foods, sugary drinks, carbonated drinks, instant foods, salty foods, seasonings, processed meat, chicken, or fish with preservatives, fatty foods, burned foods, and a lack of physical activity and the incidence of diabetes mellitus in centrally obese adults in Indonesia. Energy drink consumption had no significant association in this study.

The public is advised to change lifestyles to be healthier by reducing consumption of risky foods, increasing consumption of fruit and vegetables, and increasing physical activity to avoid diabetes mellitus and central obesity. Policymakers may be able to rethink and redesign preventive measures and interventions to prevent future increases in the prevalence of diabetes mellitus and central obesity in Indonesia. Furthermore, for future research, research is needed using prospective cohort designs in large populations in Indonesia to review more deeply the results of this research relationship.

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