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Diet quality and its correlation with blood cholesterol levels in young adults in Indonesia

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ABSTRACT

Introduction: The prevalence of hypercholesterolaemia is increasing, especially in young adults. Poor diet quality can lead to increased blood cholesterol levels. This study aimed to describe diet quality and investigate the correlation of its components with blood cholesterol levels. **Methods:** The design of this study was cross-sectional, involving 100 young adults (males and females) aged 19-22 years, chosen using purposive sampling based on inclusion criteria. Diet quality data were collected using a 3x24-hour food record and assessed using the USA-adapted Alternate Healthy Eating Index (AHEI) comprising 11 components. Data of AHEI's components were analysed using Pearson's Product Moment, Spearman's rank test, and multiple linear regression. **Results:** All young adults' diet quality (100%) had a score in the 'needed improvement' category (<76.2). There were no significant correlations between fruits (r=-0.129, p=0.200), tubers and cereals (r=-0.071, p=0.482), nuts and legumes (r=0.169, p=0.093), red processed meat (r=-0.043, p=0.670), omega-3 (r=0.022, p=0.831), polyunsaturated fatty acids (r=-0.056, p=0.581), sodium (r=-0.061, p=0.544), and alcohol with blood cholesterol levels. However, there was a significant correlation between vegetables (r=-0.226, p=0.024), sugar-sweetened beverages (SSB) (r=0.388, p<0.001), and *trans* fat (r=0.237, p=0.018) with blood cholesterol levels. **Conclusion:** Consumption of vegetables was associated with decreased blood cholesterol levels, while SSB and *trans* fat consumption were associated with increased blood cholesterol levels.

Keywords: AHEI, cholesterol, diet quality, young adult

INTRODUCTION

Hypercholesterolaemia is a condition characterised by elevated levels of total cholesterol in the blood, typically exceeding 5.17 mmol/L, and it is a leading cause of cardiovascular disease-related deaths (Kemenkes, 2018; Malaeny Katuuk & Onibala, 2017). The results of the 2018 Riskesdas (Indonesia's Basic Health Research) showed that 28.8% of Indonesians aged >15 years have cholesterol levels above the threshold or high (Kemenkes, 2018). An individual with hypercholesterolaemia is at a 9.2 times greater risk of developing coronary heart disease (CHD) (Malaeny *et al.*, 2017). Elevated blood cholesterol from age 18 years and above, often driven by

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unhealthy diets, increases the risk of CHD later in life (Sari *et al.*, 2024).

A study indicated that 55.0% of university students aged 20-23 years at Semarang State University have low diet quality (Meha, 2022). Diet quality is used to evaluate food intake based on a diet quality score, which is considered good when intakes of macronutrients (carbohydrate, protein, fat) and micronutrients (vitamins and minerals) meet the body's requirements in appropriate amounts; it is considered poor when energy and fat intakes are excessive, while dietary fibre is low. Foods high in energy and fat, especially saturated fat, can increase fat deposits in the liver, leading to elevated blood cholesterol levels (Leech *et al.*, 2015).

The Alternate Healthy Eating Index (AHEI) is a modified version of the Healthy Eating Index (HEI), designed to prioritise food groups and nutrients associated with a higher risk of non-communicable diseases (NCDs). AHEI incorporates components like omega-3, *trans* fat, and polyunsaturated fatty acids (PUFA), as these are strongly associated with the risk of NCDs, such as type 2 diabetes mellitus and CHD (Chiuve *et al.*, 2012). Observing the consequences of hypercholesterolaemia, this research aimed to investigate the relationship between diet quality and its components with blood cholesterol levels.

METHODOLOGY

The study design was cross-sectional. This study obtained ethical clearance from the Health Research Ethics Committee, Faculty of Health Sciences, Jenderal Soedirman University, with the following number: 1030/EC/KEPK/II/2023. The population of this study was young adults (males and females) aged 19-25 years in Banyumas Regency, Central Java, Indonesia. A total of 100 subjects were selected using purposive sampling according to inclusion and exclusion criteria. The inclusion criteria were college students aged 19-25 years. The exclusion criteria were those taking any medications to lower blood cholesterol levels, on specific diets, with family-diagnosed hypercholesterolaemia, smokers, and with incomplete data. Respondents who met the inclusion and exclusion criteria were then provided with detailed explanations of the study, an information sheet, and informed consent before the data collection process. Data were collected by enumerators under the supervision of the researchers from February to March 2023. Before data collection, the researchers provided training on data measurement and questionnaire completion.

Sociodemographic data

Sociodemographic data collected in this study were age, gender, residential status, and monthly pocket money. Sociodemographic data were collected through interviews using a questionnaire. Residential status was classified into two categories: living with parents or living in a boarding house. Monthly pocket money was classified into three categories: less than Rp 500,000, Rp500,000-1,000,000, and >Rp1,000,000 (USD 1 = IDR 16,350 as of 11 February 2025).

Anthropometric measurements

Anthropometric measurements conducted in this study were height, body weight, and body mass index (BMI). Height was measured using a stadiometer (SAGA, Cianjur, Indonesia), with a precision level of 0.1 cm. To measure height, respondents removed their shoes, hats, and hair accessories before measuring their height. Afterwards, they stood upright on the stadiometer with their heels, back, and buttocks touching the measuring rod.

Body weight and BMI were measured using bioelectrical impedance analysis (BIA) (Omron Karada Scan Body Composition Monitor HBF-375, Singapore). Respondents' characteristics, such as age, gender, and height, were inputted into the BIA to measure BMI. Once the device was calibrated, respondents stood on the BIA with minimal clothing and without using additional accessories. The BIA measured weight and calculated BMI directly, with a precision level of 0.1 kg for body weight. BMI was categorised into four: underweight (<18.5 kg/m^2), normal (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2), and obesity (≥30 kg/m^2) (Kemenkes, 2018).

Blood cholesterol levels

Data on blood cholesterol levels were collected using a glucose, cholesterol, and uric acid (GCU) meter device (Easy Touch GCU, Bioptic Technology, Taiwan). Examination of blood cholesterol levels was conducted after respondents had fasted for eight hours. Once the device was calibrated, blood sampling was done by pricking the cleaned fingertip of the respondent using a lancet. The blood extracted was then placed on a test strip installed in the provided cholesterol meter. Test methods were applied according to standard procedures in the user guide. The Easy Touch GCU is deemed reliable based on the manual, as each cholesterol chip and strip has its code, ensuring accurate results when using chips and strips with the same code. The Easy Touch GCU also performs automatic calibration each time it is used. Blood cholesterol levels were classified as normal (<5.17 mmol/L), borderline (5.17-6.18 mmol/L), and high (≥6.21 mmol/L) (Kemenkes, 2018).

Table 1. Alternate Healthy Eating Index modification for Indonesia

No.	*Components*	*Minimum score (0)*	*Maximum score (10)*
1.	Vegetables (portion)[†]	0 portion	3-4 portions
2.	Fruits (portion)[‡]	0 portion	≥5 portions
3.	Tubers and cereals (g)[§]	0g	≥100 g
4.	SSB (portion)[¶]	≥1 portion	0 portion
5.	Nuts and legumes (portion)[††]	0 portion	3 portions
6.	RPM^2 (portion)[‡‡]	≥1.5 portion	0 portion
7.	*Trans* fat (% energy)	≥4% energy	≤0.5%energy
8.	Omega-3 (mg)	Male 0 mg Female 0 mg	Male ≥160 mg Female ≥110 mg
9.	PUFA (% energy)	≤2% energy	≥10%energy
10.	Sodium (mg)	>2000 mg	≤2000 mg
11.	Alcohol (portion) [§§]	Male ≥3.5 portion Female ≥2.5 portion	Male 0.5-1.5 portion Female 0.5-1.0 portion

SSB: Sugar-sweetened beverages; RPM: Red processed meat; PUFA: Polyunsaturated fatty acid

[†]1 portion is equivalent to a glass of vegetables (100 g)

[‡]1 portion is equivalent to one medium-sized Ambon banana (75 g) or as per the standard serving size for fruits

[§]1 portion is equivalent to 0.75 cups of oatmeal or rice (100 g)

[¶]1 portion is equivalent to 8 oz (226.8 ml) of liquid

[††]1 portion is equivalent to two medium-sized pieces of tempeh (50 g) or according to the standard serving size for legumes

[‡‡]1 portion is equivalent to one medium-sized slice of beef (35 g) or as per the standard serving size for red processed meat

[§§] 1 portion is equivalent with one glass or equivalent to 4 oz of red wine

Diet quality
Food intake data were collected using a 3x24-hour estimated food record, conducted over two weekdays and a weekend day. During data collection, respondents were given a guidebook and were asked to send photos of their food before and after consumption through WhatsApp. The photos were used to validate the portion sizes written in the food records. Food records were then processed using AHEI, which consists of 11 components, including vegetables (portion), fruits (portion), tubers and cereals (g), sweetened beverages (portion), nuts and legumes (portion), red processed meat (portion), *trans* fat (% energy), omega-3 (mg), PUFA (% energy), sodium (mg), and alcohol (portion), which had been adjusted in components and portions against the Indonesian Dietary Guidelines, with an α-Cronbach value of 0.61 (Table 1) to assess diet quality (Briawan, Nurpratama & Riyadina, 2020; Putri, Briawan & Ekayanti, 2018). AHEI components that were not found in the Indonesian Food Composition Table (FCT) were obtained from the Thailand, Singapore, Australia, and USDA FCTs. AHEI components have a range score of between 0-10. The maximum score of AHEI (by summing up each component) is 110. The formula used for calculating the score is as follows:

$$\text{Score} = \frac{\textit{(Food component that has been consumed in a day)}}{\textit{(Maximum score of AHEI)}} \times 10$$

For instance, a man consumed three portions of fruit in a day. The fruit component score was calculated as 93 divided by 5 (maximum criteria of the vegetable component) and multiplied by 10. Hence, the fruit component score for the man was 6. The total AHEI scores

Table 2. Characteristics of subjects based on blood cholesterol levels

Characteristic	*Blood cholesterol levels*					
	Normal		*Borderline*		*High*	
	n	*%*	*n*	*%*	*n*	*%*
Gender						
Male	19	76.0	5	20.0	1	4.0
Female	33	44.0	38	50.7	4	5.3
Age						
19-25 years old	52	52.0	43	43.0	5	5.0
Residential status						
Boarding house	41	53.9	30	39.5	5	6.6
Living with parents	11	45.8	13	54.2	0	0.0
Monthly pocket money (IDR)*						
<Rp 500,000	7	50.0	7	50.0	0	0.0
Rp 500,000-Rp 1,000,000	21	42.9	23	46.9	5	10.2
>Rp 1,000,00	24	64.9	13	35.1	0	0.0
Body mass index (BMI)						
Underweight (<18.5 kg/m^2)	8	50.0	7	43.8	1	6.2
Normal (18.5-24.9 kg/m^2)	38	52.8	30	41.7	4	5.5
Overweight (25.0-29.9 kg/m^2)	6	50.0	6	50.0	0	0.0
Diet quality						
Need of improvement (<76.2)	52	52.0	43	43.0	5	5.0
Good for diet quality (≥76.2)	0	0.0	0	0.0	0	0.0

*USD 1 = IDR 16,350 (as of 11 February 2025)

Table 3. Mean, median, standard deviation (SD), and range of variables for monthly pocket money, body mass index, diet quality, and cholesterol levels

No.	*Variables*	*Mean±SD*	*Median*	*Range*	
				Minimum	*Maximum*
1.	Monthly pocket money (IDR)	1,152,600±781,735	1,000,000	150,000	5,600,000
2.	Body mass index (kg/m^2)	21.4±3.3	21.0	14.6	34.3
3.	Diet quality	36.2±6.9	36.0	16.0	55.0
4.	Cholesterol levels (mmol/L)	10.9±1.5	11.0	6.6	14.8

*USD 1 = IDR 16,350 (as of 11 February 2025)

were categorised into two categories according to the highest quartile: good if ≥76.2 and needed improvement if <76.2 (Chiuve *et al.*, 2012).

Statistical analysis

Data were analysed using IBM SPSS Statistics for Windows version 26.0 (IBM Corp, Armonk, New York, USA). Univariate data of respondents' characteristics (age, gender, place of residence, monthly income) and univariate data of research variables were presented as cross-tabulations with blood cholesterol levels.

Diet quality and blood cholesterol levels were also tested for normality using the Kolmogorov-Smirnov test. Data were analysed using Pearson's Product Moment if data distribution was normal or Spearman's rank test if data distribution was abnormal to assess the correlation between diet quality and blood cholesterol levels. AHEI components with a *p*-value <0.25 were analysed with multiple linear regression to determine whether these variables could influence total cholesterol levels.

RESULTS

Participants' characteristics

Table 2 showed that 76.0% of males had normal cholesterol levels, while 50.7% of females had borderline cholesterol levels. Subjects aged 19-25 years (52.0%) had normal cholesterol levels. Subjects who lived with their parents (54.2%) had borderline cholesterol levels. All subjects in this research were college students. Subjects with pocket money (IDR) ≥Rp 1.000.000 per month (64.9%) had normal cholesterol levels. Subjects with a BMI category of overweight (54.5%) had borderline cholesterol levels. All subjects required improvement in their diet quality. Table 3 shows the average monthly pocket money Rp. 1,152,600, BMI (21.4 kg/m^2), diet quality score (36.2), and cholesterol levels (10.9 mmol/L) of subjects.

Subjects' food consumption and AHEI scores

Table 4 showed that the average intake of vegetables (0.45 portions), fruits (0.38 portions), nuts and legumes (0.57 portions), and PUFA (5.46% energy) was below the recommended dietary allowance. Meanwhile, the average consumption of sweetened beverages (0.89 portions), red processed meat (0.06 portions), and *trans* fatty acids (0.68% energy) exceeded the recommended dietary allowance. Table 4 also showed that alcohol had the highest AHEI score (10) because all subjects did not consume alcohol. In contrast, vegetables had the lowest score (1.50), where the average individual consumption was 0.45 portions.

Correlations between components of diet quality and blood cholesterol levels

Table 4 showed that there were no

Table 4. Subjects' food consumption, Alternate Healthy Eating Index (AHEI) scores, and correlations between AHEI components with blood cholesterol levels

No.	*Components*	*Consumption Mean±SD (Median)*	*AHEI score Mean±SD (Median)*	*Blood cholesterol levels*	
				p-value	*r*
1.	Vegetables (portion)[†]	0.45±0.22 (0.42)	1.50±0.74 (1.40)	0.021*	-0.231
2.	Fruits (portion)[‡]	0.38±0.45 (0.21)	0.76±0.90 (0.42)	0.200[§]	-0.129
3.	Tuber and cereals (g)[‡]	177.9±77.1 (168.8)	9.67±10.00 (1.24)	0.482	-0.071
4.	SSB (portion)[‡]	0.89±0.62 (0.76)	2.72±2.83 (1.18)	<0.001*	0.389
5.	Nuts and legumes (portion)[‡]	0.57±0.52 (0.44)	1.90±1.75 (1.18)	0.093[§]	0.169
6.	RPM[2] (portion)[‡]	0.06±0.13 (0.00)	9.58±0.85 (10.00)	0.670	-0.043
7.	*Trans* fat (% energy)[‡]	0.68±3.02 (0.34)	9.50±1.24 (10.00)	0.016*	0.240
8.	Omega-3 (mg)[‡]	275.3±192.8 (200.0)	8.77±2.43 (10.00)	0.831	0.022
9.	PUFA (% energy)[‡]	5.46±1.83 (5.31)	5.31±1.73 (5.21)	0.581	0.056
10.	Sodium (mg)[‡]	1056±571 (981)	9.40±2.39 (10.00)	0.544	-0.061
11.	Alcohol (portion)	0.00±0.00 (0.00)	10.00±0.00 (10.00)	-	-

SSB: Sugar-sweetened beverages; RPM: Red processed meat; PUFA: Polyunsaturated fatty acid

[†]Analysed using Pearson's Product Moment

[‡]Analysed using Spearman's rank test

[§]*p-value* <0.25 analysed in multiple linear regression

***p-value* <0.05 shows a significant association (vegetables, SSB, and *Trans* fat)

significant correlations between fruits (*p*=0.200), tubers and cereals (*p*=0.482), nuts and legumes (*p*=0.093), red processed meat (*p*=0.670), omega-3 (*p*=0.831), PUFA (*p*=0.581), or sodium (*p*=0.544) with blood cholesterol levels. However, there was a negative correlation between vegetables and blood cholesterol levels (*p*=0.024, *r*=-0.226) and a positive correlation between sugar-sweetened beverages (SSB) (*p*<0.001, *r*=0.388) and *trans* fatty acids (*p*=0.018, *r*=0.237) with blood cholesterol levels.

Contributions of AHEI components to blood cholesterol levels

Table 5 shows the multiple linear regression analysis using five variables with a *p*<0.25 (vegetables, fruits, nuts and legumes, *trans* fat, and SSB). Multiple linear regression showed that only SSB was significantly correlated with blood cholesterol levels (*p*=0.036). The coefficient of determination analysis also showed that consuming SSB could explain cholesterol levels by 11.8%, while other variables outside this study demonstrated the remaining 88.2%.

DISCUSSION

This cross-sectional study aimed to determine the correlations between components of AHEI as a tool for measuring diet quality and blood cholesterol levels in young adults. Table 2 indicated that 76.0% of males had normal cholesterol levels, whereas 50.7% of females had borderline cholesterol levels. Women are at a higher risk of elevated blood cholesterol due to greater body fat retention, higher subcutaneous fat, and less internal white adipose tissue compared to men. Furthermore, women also demonstrate a higher rate of triglyceride synthesis when compared to men. These factors increase women's susceptibility to elevated cholesterol levels (Li *et al.*, 2021).

The study participants were between 19 and 25 years old (Table 2). Most respondents (52.0%) had normal cholesterol levels, but levels tended

Table 5. Multiple linear regression analyses of blood cholesterol levels (dependent variable) and selected independent variables

Model	*Unstandardised coefficients*		*Standardised coefficients*	*t*	*p-value*
	Beta	*Std. Error*	*Beta*		
Vegetables	-22.732	12.358	-0.188	-1.839	0.069
Fruits	-6.428	5.857	-0.108	-1.097	0.275
SSB	9.186	4.311	0.213	2.131	0.036
Nuts and legumes	5.216	4.997	0.102	1.044	0.299
Trans fat (% energy)	0.472	0.882	0.053	0.535	0.594

R^2=0.118; Adjusted R^2=0.071; F=2.505; p=0.036

to rise after age 20. Uncontrolled cholesterol in young adulthood can result in prolonged low-density lipoprotein (LDL) exposure, accumulating in blood vessels and forming plaques that lead to coronary heart disease (Zhang *et al.*, 2021). Subjects with BMI categories of overweight (54.5%) had borderline cholesterol levels (Table 2). Individuals with overweight status reportedly have cholesterol levels that are 30.0% higher compared to someone with a normal body weight and nutritional status; they are at a higher risk of having high total blood cholesterol levels (Al-Zahrani *et al.*, 2021).

Diet quality assessment compares the food components consumed with the recommended intake levels of each diet quality component. AHEI consists of foods and nutrients that predict non-communicable disease risk (Chiuve *et al.*, 2012). The research results indicated that 100.0% of the respondents had diet quality scores categorised as needing improvement. This suboptimal diet quality could be attributed to various factors, including cultural and eating habits, socioeconomic status, and family food preferences. When young adults leave their family homes, they often adopt unhealthy eating habits, including reduced intake of fruits and vegetables, irregular meals, and increased consumption of unhealthy snacks. Socioeconomic status also influences food consumption. Individuals with higher household incomes have more choices when purchasing food, leading to a more diverse dietary intake (Sogari *et al.*, 2018).

The results showed that the average vegetable and fruit consumption were 0.45 and 0.38 portions a day, respectively (Table 4), less than the daily recommendation. The low consumption of vegetables among the research respondents can be attributed to a significant portion of them living independently. Young adults living independently often exhibit a decreased concern for their dietary habits due to being away from the supervision of their parents. Additionally, young adults who live independently prefer buying food from local eateries over cooking at home, which means that vegetable dishes that do not align with their preferences are also a reason they do not consume vegetables (Dhaneswara, 2016).

The findings also showed that there was no relationship between fruit consumption and total blood cholesterol levels (p>0.05) (Lestari & Utari, 2017) (Table 4). Another study showed that consuming three or more servings of fruit per day was associated with 4.11 mg/dL lower LDL cholesterol levels compared to those who consumed less than one serving per day (Becerra-Tomás *et al.*, 2021). However, the average daily consumption of respondents was only 0.38 servings, which could make the results insignificant. The low fruit consumption compared to their daily vegetable intake also indicated that fruit was not the primary source of fibre for the respondents.

Meanwhile, there was a relationship between vegetable consumption and total blood cholesterol levels, with a correlation coefficient of -0.214 (Table 4). A negative correlation coefficient indicates a relationship in the opposite direction, where the lower the consumption of vegetables, the higher the total blood cholesterol level. This aligns with research that showed vegetable intake was correlated with lower serum cholesterol levels (Hansen *et al.*, 2009).

Vegetables and fruits are a group of foods that are high in fibre, which can help to prevent hypercholesterolaemia (Sari *et al.*, 2024). This happens because fibre binds to the end of the cholesterol product, namely bile salts, in the digestive tract, which will be excreted along with the faeces. This excretion of cholesterol through faeces causes the cholesterol level circulating through the blood to the liver to decrease so that the liver will increase the production of cholesterol into bile acids. This causes total cholesterol levels in blood plasma to decrease (Martini *et al.*, 2021).

The results showed no correlation between tubers and cereals with blood cholesterol levels. The average consumption of tubers and cereals was 177.9 grams daily (Table 4), which aligned with the daily recommendation to consume ≥100 grams daily. Nevertheless, the average consumption of tubers and cereals remained lower than in previous research, which was 447.5 grams per day (Putri *et al.*, 2018). Based on the dietary records, most respondents consumed white rice as their source of staple food. Other kinds of tubers and cereals that they consumed were noodles (cerealia), cassava (tuber), and potatoes (tuber). There are different ways tubers and cereals affect blood cholesterol levels. Tubers contain various bioactive compounds that help maintain a balanced blood lipid profile by lowering LDL cholesterol levels (Christamanda & Estiasih, 2015). On the other hand, white rice, as a source of cereal, has a high glycemic index; regular consumption can change the metabolic system, resulting in decreased high-density lipoprotein (HDL)-cholesterol concentration, increased oxidative stress and endothelial dysfunction. The difference between each group of this component might explain the absence of a relationship in this study.

Results showed that the average SSB consumption was 0.89 portions a day and indicated a relationship between the portion size of sweetened beverages and total blood cholesterol levels, with a correlation coefficient of 0.394. A positive correlation coefficient suggests that as the portion size of sweetened beverages consumed increases, the total blood cholesterol levels also tend to rise. This is consistent with a previous study that found a significant relationship between sweetened drinks and total cholesterol levels (Sari *et al.*, 2024). Excessive fructose intake from SSB can be metabolised into fat in the liver, triggering *de novo* lipogenesis, atherogenic dyslipidaemia, insulin resistance, and increasing very-low-density lipoprotein (VLDL) secretion, elevating blood lipid levels (Malik & Hu, 2022). The relationship between sweetened beverages and total blood cholesterol levels has the strongest correlation compared to the correlation coefficients of other diet quality components. This suggests that sweetened beverages significantly impact cholesterol levels compared to the other ten components.

Results showed that the average nuts and legumes consumption was

0.57 portions a day (Table 3). This average consumption fell below the recommended daily intake of more than three portions. Young adults who lived with their parents notably consumed more legumes and nuts than those who did not reside with their parents. This difference in consumption patterns could be attributed to young adults having less responsibility for meal planning and preparation when living with their families, as their parents consistently encouraged and supported them in making healthy dietary choices (Sari *et al.*, 2024). Legumes are a food group rich in unsaturated fatty acids, vitamins, minerals, fibre, antioxidants, and phytochemicals such as flavonoids and sterols. Bioactive compounds in legumes reduce VLDL production, thus improving blood lipid profiles (Zhang *et al.*, 2010). Additionally, their high fibre content binds cholesterol as bile salts, promoting excretion and lowering cholesterol levels (Martini *et al.*, 2021).

Based on Table 4, the research results showed no relationship between nuts and legumes consumption with total blood cholesterol levels. This finding contrasts a previous study showing that daily nut consumption reduced total cholesterol by 10.9 mg/dL, while legumes lowered it by 7% (Afshin *et al.*, 2014). Martini *et al.* (2021) also reported that consuming 62 grams of nuts daily significantly reduces total cholesterol. However, Gunathilake, Van & Kim (2022) found no consistent effect of nuts on lipid profiles, suggesting variability depending on the type of nuts. The respondents' daily intake of nuts and legumes, which was only 0.57 servings per day, might explain why the difference in blood cholesterol levels were insignificant.

Results showed that the average daily consumption of red processed meat (RPM) was 0.06 portions (Table 4). This consumption nearly reached the maximum score for diet quality, which is 0 portions per day. This research finding aligns with a previous study, which assessed diet quality using the same instrument and found an average daily consumption of 0.40 portions of red processed meat (Putri *et al.*, 2018). The research also showed no relationship between the consumption of red processed meat and total blood cholesterol levels. This finding did not align with a previous study showing individuals who consumed more than 0.58 portions of processed meat daily were at risk of increased LDL cholesterol and total blood cholesterol levels (Cha & Park, 2019). Red processed meat is a food source with high animal protein content. However, this type of food also contains high cholesterol and saturated fats. The research subjects consumed an average of only 0.06 portions of red processed meat, indicating minimal to no consumption. This extremely low intake likely contributed to an insignificant relationship between red processed meat consumption and blood cholesterol levels.

This study showed that the average *trans* fat intake was 0.06 portions a day (Table 4). This average consumption of *trans* fats exceeded the maximum score in the assessment of diet quality, which is ≤0.5% of energy intake. The consumption of *trans* fat exceeding daily recommendations may be due to the significant number of respondents consuming fried foods, such as fried chicken, fried *tempeh*, and fried snacks, based on the data of food records. The research results also indicated a relationship between *trans* fat consumption and total blood cholesterol levels, with a correlation coefficient of 0.259. A positive correlation coefficient suggests that as *trans* fat intake increases, total cholesterol levels also tend to rise. High *trans fat* intake can lead to an increase in LDL cholesterol levels and a decrease in HDL cholesterol levels (Islam *et al.*, 2019). *Trans* fats are a result of the hydrogenation of unsaturated fatty acids. Saturated fatty acids (SFA) are sensitive to heat. The frying process in food preparation can form long-chain saturated fatty acids and *trans* fatty acids (Putri *et al.*, 2018). Therefore, frequent consumption of fried foods can lead to an excessive intake of *trans* fats. An increase in *trans* fat intake by 2% can increase the risk of coronary heart disease by 23% through an increase in LDL cholesterol levels (Islam *et al.*, 2019).

The results showed no correlation between PUFA and blood cholesterol levels. The study also showed that the average PUFA consumption was 5.46% of daily energy intake (Table 3). This average daily PUFA consumption did not yet reach the maximum score for the diet quality component, categorised as ≥10% of total energy intake. A meta-analysis found that consumption of PUFA reaching 10% of total daily energy resulted in a significant reduction in LDL cholesterol and that replacing SFA with PUFA consistently reduced total cholesterol by 5-15 mg/dL (Mozaffarian, Micha & Wallace, 2010). The average PUFA consumption, which was below 10%, could be due to respondents' infrequent consumption of high-PUFA foods, including fish, nuts, and legumes, attributing to insignificant results in this research.

Results showed that the average omega-3 consumption was 275.3 mg daily (Table 4). This average consumption met the maximum score for the diet quality component, which is more than 160 mg per day. The research results also indicated no relationship between consumption of omega-3 and total blood cholesterol levels (Table 4). This finding contradicts a previous study, suggesting that consuming fish containing omega-3 can lower non-HDL cholesterol levels. Consuming fish, a source of omega-3, could lower total cholesterol levels by inhibiting VLDL and triglyceride synthesis in the liver (Tani *et al.*, 2020).

This research indicated no relationship between sodium consumption and blood cholesterol levels, with the respondents' daily sodium intake being only 1056 mg, which was within the daily sodium consumption limit of less than 2000 mg. A previous study reported a positive relationship between sodium intake and total cholesterol levels (Bu *et al.*, 2012). However, the current study finding aligns with the meta-analysis results of Aburto et al. (2013), which showed that reduced sodium intake did not have an inverse, significant effect on total cholesterol levels.

The research results showed none of the subjects consumed alcohol. This result is closely similar to a previous research done in Malaysia, which had the same background as in Indonesia (Muslim majority). According to the National Health and Morbidity Survey in 2015, 8.4% of people aged 18 years consumed alcohol (Jaimon, Deligannu & Robinson, 2023).

The results of multivariate analysis showed that consuming sugar-sweetened beverages was associated with blood cholesterol levels. Consuming sweetened drinks is one of the factors that triggers an increase in blood cholesterol levels. A previous study showed that individuals who consumed sugary drinks had a higher risk of elevated levels of total cholesterol by 6.167 times (Sari *et al.*, 2024). Another study showed that respondents who consumed SSB daily had 1.6 mg/dL higher total cholesterol than non-consumers of SSB (Sigala *et al.*, 2021). The intake of sugary drinks raises total cholesterol levels through several mechanisms. Fructose, a key component of sugary drinks, is metabolised in the liver, bypassing glycolysis regulation and directly fuelling *de novo* lipogenesis, leading to excess VLDL production.

Additionally, fructose impairs the liver's LDL receptors, reducing the clearance of LDL cholesterol from the bloodstream. This results in elevated circulating LDL cholesterol, contributing to higher total cholesterol levels (Malik & Hu, 2022).

This study has several limitations. The sample size was small and completing the lengthy questionnaires posed a challenge. Data collection using the food record method relied heavily on respondents' honesty and memory, introducing potential bias. To mitigate this, respondents were asked to photograph their meals before and after eating. Additionally, accurately estimating added salt in food ingredients was difficult, leading to reliance on approximations that may affect study accuracy. For *trans* fat intake analysis, results were based only on the oil content used during food preparation, without accounting for the duration of oil use, which also impacts *trans* fat levels. As a cross-sectional study, this research measured exposure and outcomes simultaneously, limiting its ability to establish causal relationships and serving primarily to generate initial hypotheses.

CONCLUSION

In conclusion, this study showed that all respondents had diet quality scores that needed improvement, with the average consumption of vegetables, fruits, and nuts still low and not meeting daily requirements. This study also implied that increased consumption of vegetables may be linked to lower blood cholesterol levels. In contrast, consuming SSB and *trans* fat was associated with elevated blood cholesterol levels. Multivariate analysis showed that the consumption of SSB contributed to elevated blood cholesterol levels by 11.8%. Future studies could adopt case-control or cohort designs to explore causal relationships more effectively. Researchers also recommend investigating additional variables, such as physical activity, stress levels, sleep quality, and other lifestyle factors, to provide a more comprehensive understanding of diet and lifestyle influences.

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Authors' contributions

Hesti PS, principal investigator, conceptualised and designed the study, interpreted the study results, prepared the draft of the manuscript, and reviewed the manuscript. Apoina K, advised on data analysis and help revised the manuscript, Yudhi D, advised on drafted revised manuscript. Nurjazuli N, advised on data analysis and revised manuscript. Afina RS, advised on the collection of data and interpretation. Elok W, led the data collection and assisted in the drafting of the manuscript.

Conflict of interest

The authors declare that there are no significant competing financial, professional or personal interests that might have affected the performance or presentation of the work described in this manuscript.

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