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Nutritional Status and Blood Glucose in Adolescents: Evidence from Luwuk Banggai, Indonesia

Dwi Wahyu Balebu[1,3*], Ridwan Amiruddin[2], Nurhaedar Jafar[2], A. Arsunan Arsin[2], Veni Hadju[2], Muhammad Syafar[2], Lalu Muhammad Saleh[2], Erni Yusnita Lalusu[3], Anwar Mallongi[2]

[1]The Doctoral Study Program of Public Health Faculty Hasanuddin University, Indonesia
[2]Faculty of Public Health, Hasanuddin University, Indonesia
[3]Faculty of Public Health, Tompotika University, Indonesia
Email: dwiwahyubalebu90@gmail.com
*Corresponding Author

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ABSTRACT
This study was conducted to analyze the relationship between nutritional status, waist circumference, and body mass index (BMI) with fasting blood glucose levels in adolescents in South Luwuk District. The incidence of Diabetes Mellitus (DM) among adolescents has been increasing, primarily due to lifestyle and dietary changes. This research aims to fill the knowledge gap regarding the relationship between central obesity and blood glucose levels in the adolescent age group. Using a cross-sectional design, data were collected from 276 adolescents, and the analysis was carried out using the Chi-square test to identify the relationships between these variables. The results of the study indicated a significant relationship between gender, age, and BMI with blood glucose levels, while no significant relationship was found between waist circumference and blood glucose levels. This research contributes to understanding the risk factors of DM in adolescents and highlights the importance of proper nutritional interventions as preventive measures.

Keywords: adolescents; blood glucose; diabetes mellitus; nutritional status; obesity

INTRODUCTION

Non-communicable diseases (NCDs) remain a significant global health issue, contributing to the global burden on public health and impacting the economy of societies. One of the NCDs that continues to be a priority in various countries is Diabetes Mellitus (DM). DM is also one of the diseases prioritized nationally, particularly as a degenerative condition[1]. Generally, DM occurs in the elderly, but over time, there has been an epidemiological transition, leading to DM being increasingly observed in adolescents and children. According to data from the International Diabetes Federation, DM among individuals aged 14-19 years has reached 1.1 million cases. Moreover, the prevalence of DM among children and adolescents was 7.2% in 2015. In Indonesia, the number of DM cases in adolescents aged 15–24 years is recorded at 159,014 individuals[2].

Diabetes Mellitus (DM) is a chronic metabolic disorder. It is characterized by elevated blood glucose levels, commonly referred to as hyperglycemia, which results from an imbalance between the body's insulin needs and availability. Insulin is necessary for helping glucose enter cells, where it is used for growth and cellular metabolism[3]. DM can be classified into several types, including Type I DM, Type II DM, gestational DM, and others. Among these, Type II DM is the most common, accounting for 90-95% of all DM cases[4]. Type II DM is frequently caused by lifestyle factors such as diet and physical activity. In addition, age (typically occurring after the age of 40) and obesity are contributing factors[3].

Data from the 2013 Basic Health Research in Indonesia indicated a DM prevalence rate of 6.9%. By 2018, this had increased to 8.5%. However, in 2023, the prevalence of DM, based on SKI data, showed a decline to 1.7%[5]. In Banggai Regency, there were 11,613 DM cases recorded in 2020, 9,546 cases in 2021, and 4,558 cases in 2022. One of the areas with a high number of DM cases in Banggai Regency is South Luwuk Subdistrict, where 237 cases were recorded in 2022, placing it among the top five areas with the highest number of DM cases in Banggai Regency[6], [7], [8].

The high prevalence of DM and the significant financial burden associated with type 2 DM necessitate preventive efforts through the early identification of risk factors to prevent the onset of diabetes. Nutritional status is one of the key factors that play a role in the incidence of type 2 DM. This is because individuals with obesity are more likely to develop insulin resistance, which can trigger type 2 DM. An abnormal nutritional status can also lead to various complications in individuals who already have type 2 DM[9]. Additionally, nutritional status influences blood glucose levels, which are closely related to Body Mass Index (BMI). This is due to an imbalance between energy intake and expenditure in individuals with excessive nutritional status, leading to fat accumulation from energy storage[10].

This excessive fat accumulation can reduce the response of β-cells to glucose levels in the blood, triggering insulin resistance and decreasing the amount of insulin available, which cannot be effectively utilized by the body. In individuals with excess body weight, leptin levels increase. Leptin is a substance that plays a role in maintaining energy homeostasis in the body. An increase in leptin levels can raise blood glucose levels[3].

Previously, the issue of obesity was more prevalent in developed countries and high-income nations. However, obesity is now also on the rise in developing and low-income countries, particularly in urban environments. Obesity is increasingly common among children and adolescents, with its prevalence increasing by more than 30% compared to developed countries[11]. Obesity is closely linked to Metabolic Syndrome (MS), which is a cluster of metabolic disorders that occur in patients with this syndrome. Metabolic syndrome is defined as a group of risk factors for coronary heart disease and metabolic diseases such as type 2 DM and atherosclerosis[12].

Obesity is a condition characterized by an excess accumulation of fat in the body, making the body appear overweight[13]. Based on fat distribution, obesity can be classified into three types: central obesity, peripheral obesity, and a combination of both (central and peripheral obesity). Peripheral obesity refers to excess fat in the thighs and buttocks, giving the body a pear shape (also known as "pear type")[14]. Central obesity, or abdominal obesity, occurs when there is excess fat concentrated in the abdominal area (intra-abdominal fat), giving the body an apple-like shape (also known as "apple type")[15]. General obesity can be measured using the Body Mass Index (BMI), while central obesity is measured by waist circumference. BMI is calculated by dividing body weight (in kilograms) by the square of height (in meters), while waist circumference is measured by the circumference of the abdomen (in centimeters)[16].

The prevalence of central obesity in the population aged over 15 years in Indonesia was 18.8% in 2013, according to the Basic Health Research data. This figure increased to 26.6% in 2018 and further rose to 31% according to the 2023 Indonesia Health Survey. In Central Sulawesi, central obesity was recorded at 24.9% in 2013, 32.8% in 2018, and 33.6% in 2023. The incidence of central obesity has steadily increased over the past decade.

The increased risk of degenerative diseases, particularly type 2 DM, is closely related to central obesity[17]. To detect central obesity, waist circumference is used as an indicator[18]. According to the standards set by the Ministry of Health of the Republic of Indonesia, the safe limit for normal waist circumference is 90 cm for men and 80 cm for women. A waist circumference exceeding these limits indicates the presence of excess belly fat or visceral fat. High levels of visceral fat are strongly associated with an increased risk of metabolic syndrome (including diabetes mellitus, hypertension, and dyslipidemia), cardiovascular disease, and insulin resistance[19].

Metabolic syndrome is not a disease, but rather a collection of metabolic risk factors directly associated with non-communicable diseases, particularly atherosclerotic cardiovascular disease[12]. Adolescents who suffer from metabolic syndrome are at risk of developing type 2 diabetes mellitus and cardiovascular diseases. The purpose of this study is to analyze the relationship between gender, age, waist circumference, and BMI with fasting blood glucose levels in adolescents in the South Luwuk District.

METHOD

Study Area

The research was conducted in the South Luwuk District. This district consists of 1 village and 9 sub-districts, as shown in Figure 1 above.

Research Design

This study is an analytic study using a cross-sectional design. The population of this study consists of all adolescents aged 15-24 years in the South Luwuk District, totaling 1,528 individuals[20]. The sample size for this study was calculated using the Lemeshow formula with a 95% confidence level and a 5% precision, resulting in a minimum sample size of 276 respondents[21]. Informed consent was obtained from all study participants, and only those who agreed to participate were included in the study sample.

The independent variables in this study include gender, age, nutritional status, and waist circumference, while the dependent variable is fasting blood glucose levels. Data were collected through interviews using a questionnaire. Nutritional status was determined by calculating Body Mass Index (BMI), which is the ratio of weight to height squared. Nutritional status was categorized into four groups based on the Ministry of Health's indicators: Underweight (BMI <18.5), Normal (BMI ≥ 18.5 - 25), Overweight (BMI >25 - 27), and Obese (BMI >27). Waist circumference was used to assess central obesity, measured in centimeters (cm) using a tape measure. Central obesity risk is defined as a waist circumference of ≥ 90 cm for men and ≥ 80 cm for women. Fasting blood glucose levels were measured using capillary blood samples obtained via a glucometer.

Data analysis was conducted using scatter plots, the Chi-square test, and contingency tables to analyze the relationships between age, gender, waist circumference, and BMI with respondents' fasting blood glucose levels.

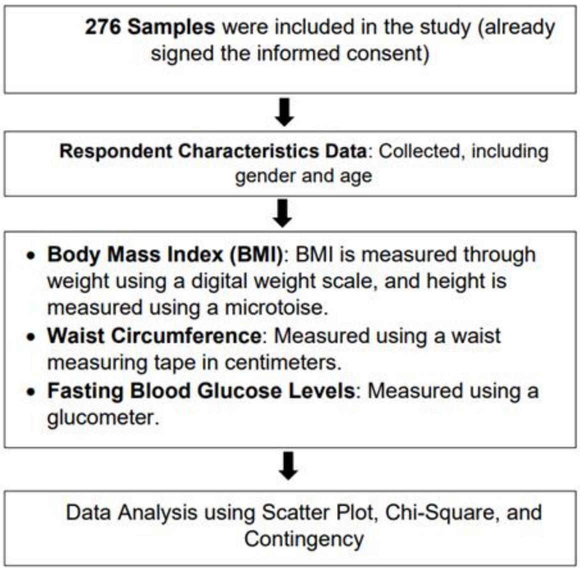

Figure 2. Research Flow

RESEARCH RESULTS

Based on the results, the frequency distribution of each variable is as follows:

Table 1. Frequency Distribution of Gender, Age, Waist Circumference, and BMI

No	Variables	n	%	Average	Min Value	Max Value
1	**Gender**					
	Woman	208	75	-	-	-
	Man	68	25			
2	**Age**					
	Adolescence (15-17 Years)	134	49	18.28	15	22
	Adolescence (18-22 Years)	142	51			
3	**Waist circumference**					
	Central Obesity	48	17	72.47	51	107
	No Central Obesity	228	83			
4	**IMT**					
	Obesity	17	6	21.26	15	34
	Fat	18	7			
	Normal	118	43			
	Thin	123	45			
5	**Blood Glucose Levels**					
	Prediabetes (<100mg/dl)	102	37	98.02	70	125
	Normal (≥100 -125 mg/dl)	174	63			
Amount		**276**	**100**	**-**	**-**	**-**

Source: Primary Data, 2024

The research results (Table 1) show that, of the 276 teenagers studied, 75% were female and 25% were male. Based on age groups, 49% of the teenagers were categorized as Early Adolescents (15-17 years), while 51%

were categorized as Late Adolescents (18-22 years), with an average age of 18.28 years. The youngest participant was 15 years old, and the oldest was 22 years old. In terms of nutritional status, 45% of the respondents were classified as underweight, while 6% were classified as obese. The average Body Mass Index (BMI) of the respondents was 22, with the lowest BMI at 15 and the highest at 34. Regarding fasting blood glucose levels, 63% of the respondents fell within the "Normal" category, while 37% were classified as prediabetic. The average fasting blood glucose level was 98.02 mg/dl, with the lowest at 70 mg/dl and the highest at 125 mg/dl.

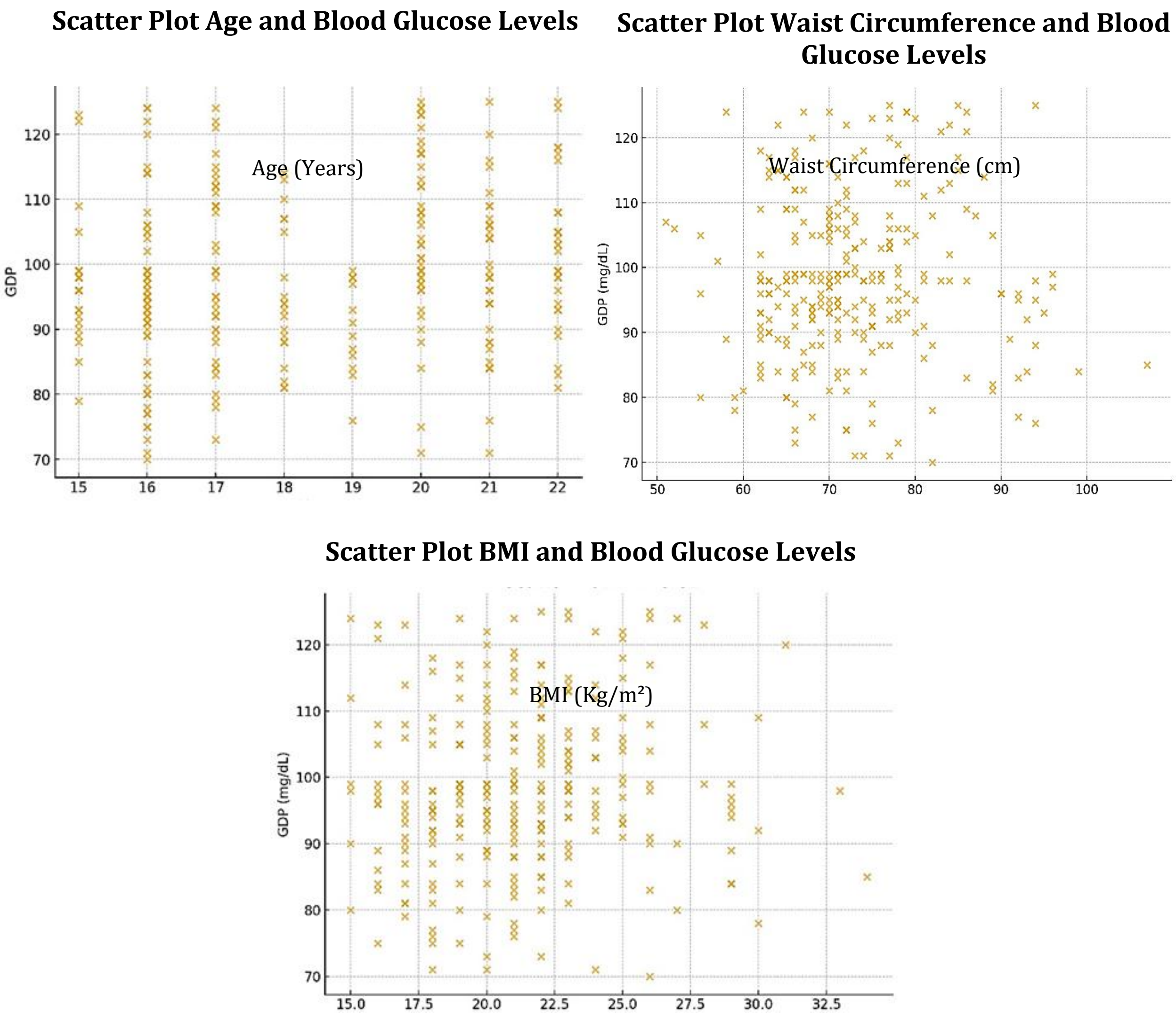

Figure 2. Scatter Plot Analysis Diagram of Age, Waist Circumference, and BMI

From the scatter plot analysis in Figure 2, it can be observed that there is no significant trend between age distribution and the blood glucose levels of the respondents. There is no clear pattern in the age distribution related to blood glucose levels, as the data points are somewhat scattered. This means that both early adolescents (15-17 years) and late adolescents (18-22 years) show varying blood glucose levels.

In the scatter plot of waist circumference and blood glucose levels, no clear pattern is observed either. A number of points are located at the top of the graph (indicating high fasting blood glucose values), which could represent outliers or individuals with significantly higher blood glucose levels compared to other respondents with similar waist circumferences. This suggests that there may be other contributing factors to the elevated blood glucose levels. In other words, an increase in waist circumference does not directly correspond to a regular increase or decrease in blood glucose levels.

In the scatter plot of BMI and blood glucose levels, a specific trend pattern emerges. At certain BMI values, there is a noticeable spread in blood glucose levels, which may indicate greater variability within this group. It can be concluded that most respondents with a low BMI (underweight) tend to have normal blood glucose levels. On the other hand, respondents with a normal BMI show a more even distribution between normal and prediabetic blood glucose levels, which may suggest an increased risk of prediabetes in this group.

Table 2. Analysis of the Relationship between Gender, Age, Waist Circumference, and BMI with Blood Glucose Levels

No	Variables	Blood Glucose Levels		Total	P Value	X^2
		Prediabetes	**Normal**			
1	**Gender**					
	Woman	89	119	208	**0,000**	**12.234***
	Man	13	55	68		
2	**Age**					
	Adolescence (15-17 Years)	36	98	134	**0.001**	**11,383***
	Adolescence (18-22 Years)	66	76	142		
3	**Waist circumference**					
	Central Obesity	16	32	48	0.511	0.527
	No Central Obesity	86	142	228		
4	**IMT**					
	Obesity	6	11	17	**0,000**	**46,671***
	Fat	7	11	18		
	Normal	18	100	118		
	Thin	71	52	123		
Amount		**102**	**174**	**276**		

Source : Primary Data, 2024

Chi-square analysis (Table 2) shows that for the variable gender, a p-value of 0.000 was obtained, which is less than 0.05. This indicates a significant relationship between gender and fasting blood glucose levels in adolescents in the South Luwuk District. For the variable age, the p-value was also 0.000, indicating a significant relationship between age and fasting blood glucose levels in adolescents.For the variable waist circumference, the analysis yielded a p-value of 0.511, which is greater than 0.05, meaning there is no significant relationship between central obesity and fasting blood glucose levels in adolescents.Finally, the chi-square analysis for the variable BMI resulted in a p-value of 0.000, which is less than 0.05, indicating a significant relationship between nutritional status and fasting blood glucose levels in adolescents in the South Luwuk District.

DISCUSSION

Gender and Blood Glucose Levels

Gender is typically classified as male and female. It is a risk factor for various diseases, including diabetes mellitus (DM). Gender influences health due to differences in immunity, hormones, and lifestyle habits between men and women. Women are at a higher risk of developing DM due to hormonal changes and metabolic differences, particularly during menstruation and menopause. These conditions can lead to fat distribution disorders in the body, increasing the risk of fat accumulation and, subsequently, higher blood glucose levels[22]. Other studies have shown that, among 60 female respondents, 48 were affected by DM. This may be due to the fact that women tend to have healthier eating patterns but also experience higher stress levels than men[23].

The results of this study show that more female adolescents suffer from prediabetes than males, and the chi-square test confirms a significant relationship between gender and blood glucose levels. These findings are consistent with previous studies, where 64.2% of respondents with high blood glucose levels were women, indicating that women are more at risk of developing DM than men[24]. Another study explained that women are more at risk due to their higher Body Mass Index (BMI) compared to men, with 52.5% of women having a BMI of 25 or more[25]. Similarly, a study conducted by Jaja and Yarhere in Nigeria also showed that women have a higher risk of developing DM compared to men[26].

Age and Blood Glucose Levels

Age is another factor related to the increase in blood glucose levels. Changes that occur with age, such as increased fat distribution, particularly central obesity, are risk factors for DM[27]. Age is a crucial risk factor for various diseases, including DM, as the body's organs function less efficiently as a person ages, leading to health problems such as increased blood glucose levels. The older a person gets, the higher their risk of developing DM. This is supported by research from Goldstein and Muller, which found that 60% of type 2 DM sufferers are over the age of 60. In Indonesia, the age threshold for DM risk, according to PERKENI, is 45 years or older[23]. In addition, aging is often associated with decreased metabolism, reduced physical activity, and increased food intake[28]. The results of this study indicate that prediabetes is more common among older adolescents (ages 18-22), with 66 individuals affected, and there is a significant relationship between age and blood glucose levels. This finding is in line with a 2019 study by Komariah, which also found a relationship between age and blood glucose levels. Older individuals, especially those over 40 years, tend to be less active and experience muscle mass reduction, which can lead to weight gain and an increased risk of DM [29]. Moreover, aging can cause damage to beta cells, tissues, the nervous system, and hormonal functions, all of which contribute to higher blood glucose levels[30]. Additionally, aging is often linked to unhealthy eating patterns, which further decline the body's metabolic function[31].

Waist Circumference and Blood Glucose Levels

Central obesity is strongly associated with elevated cholesterol levels in the body. People who experience central obesity are more likely to have disruptions in fatty acid regulation, which ultimately leads to increased levels of triglycerides and cholesterol esters. Elevated cholesterol levels can also trigger an increase in blood glucose levels, thus becoming a risk factor for the incidence of DM[32]. This theory is supported by previous research conducted by Septyaningrum, which showed a positive correlation between an increase in waist circumference and elevated blood glucose levels[33]. However, the results of this study indicate no significant relationship between central obesity and blood glucose levels in adolescents (p-value = 0.511). This result does not align with previous research conducted by Xueshan Jin, who stated that individuals with central obesity are at a higher risk of developing DM[34].

Central obesity indicates fat accumulation in the abdominal area, which is a risk factor for DM. People with central obesity may experience inflammation that triggers insulin resistance. This condition can ultimately lead to dysfunction of beta cells, which may cause pancreatic damage[35]. In this study, the lack of a relationship between central obesity and blood glucose levels could be attributed to various unmeasured confounding factors, such as physical activity, smoking habits, sugar consumption, and other lifestyle factors.

BMI and Blood Glucose Levels

Nutritional status is one of the factors that influence blood glucose levels. Body Mass Index (BMI) is a commonly used indicator for assessing nutritional status, particularly for identifying obesity. Excess fat deposits trigger increased cellular uptake of fatty acids, which in turn leads to enhanced fat oxidation. This process hinders muscle cells from utilizing glucose effectively, causing blood glucose levels to rise. This theory is supported by a previous study conducted by Masruroh in 2017, which found a significant influence of nutritional status on blood glucose levels (p-value = 0.000)[3].

The results of this study also show a significant relationship between adolescents' nutritional status and blood glucose levels, with a p-value of 0.000. These findings are consistent with a previous study by Andreasson, which found that increasing BMI in adolescents is associated with a higher risk of type 2 diabetes diagnosed at a younger age[36]. High BMI, particularly in cases of obesity, is a major risk factor for DM. The relationship between obesity and DM is complex, even when an individual's weight falls within an acceptable range, as it can still increase the risk of elevated blood glucose levels, especially when combined with other risk factors. Increased BMI is linked to DM due to the correlation between body fat and insulin resistance. Individuals with obesity tend to have higher levels of intracellular fatty acids, which are associated with insulin resistance[37].

CONCLUSION

The conclusion of this study shows a significant relationship between gender, age, and body mass index (BMI) with fasting blood glucose levels in adolescents in South Luwuk District. Meanwhile, no significant relationship was found between waist circumference and fasting blood glucose levels in the adolescent age group. These results highlight the importance of controlling nutritional status as one of the key factors in preventing diabetes mellitus (DM) at a young age. Controlling BMI and educating about healthy lifestyles should be prioritized to reduce the risk of DM among adolescents. This study provides new insights into diabetes risk factors in adolescence, which can serve as a basis for designing preventive programs in public health.

Theoretically, these findings enrich the literature on the relationship between nutritional status and diabetes in adolescents, while also strengthening the understanding of the crucial role BMI plays in influencing blood glucose levels. Practically, the results of this study can be used as a reference in developing public health intervention programs focused on BMI monitoring and empowering adolescents through nutritional education and healthy lifestyle promotion. However, this study has limitations, including not considering other factors such as physical activity and dietary intake that could affect the results. For future research, it is recommended to broaden the scope of variables studied and to use a longitudinal approach to understand changes in blood glucose levels over time. This can help deepen understanding and provide more comprehensive solutions in preventing DM among adolescents.

Ethics Approval

Before the survey began, participants were asked to read and sign an informed consent form, included on the first page of the questionnaire. This form explained the research objectives, data collection procedures, and confidentiality measures. Ethical approval for this study was obtained from the Faculty of Public Health, Hasanuddin University, Makassar, Indonesia, with reference number 410/UN4.14.1/TP.01.02/2024. The study adheres to the ethical principles established in the 'Declaration of Helsinki'.

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Competing Interests

The authors declare that there are no conflicts of interest in this study.

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