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Predictive Model of Type 2 Diabetes Risk in Early Adulthood Using a Community Based Approach in Coastal and Urban Areas

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ABSTRACT

Introduction: Type 2 diabetes mellitus (T2DM) is a growing global health problem, including in Indonesia. In Riau Province, the prevalence of type 2 diabetes is also high, with more than 90,000 cases recorded in 2023. Early detection through a risk factor prediction model is essential to prevent further complications.

Aim: This study aims to analyse a predictive model of risk factors for type 2 diabetes mellitus in early adulthood in Riau Province using an environmental approach.

Method: This study used a quantitative design with a survey method to explore the correlation and interaction between environmental exposure and risk factors for T2DM in young adults (aged 18–45 years). A total of 791 respondents were randomly selected as the sample. Data analysis was performed using multivariate analysis with Partial Least Squares Structural Equation Modeling and significance testing through bootstrapping with a significance level of 5%.

Results: The results of the analysis indicate that determinants of consumption behaviour have a significant influence on the risk of type 2 diabetes (P=0.000). However, lifestyle factors and individual characteristics do not significantly influence the risk of diabetes in the early adult age group (P>0.05). The prediction model shows the highest R^2 value for the consumption behaviour variable (0.242), with a Q^2 value of 0.864, indicating a good model for predicting diabetes risk factors.

Conclusion: The present study demonstrates that the consumption of sweet foods and associated dietary habits is significantly associated with an increased risk of type 2 diabetes. It is evident that environmental factors, including but not limited to air pollution and noise, significantly impact the risk of developing diabetes. Implementing policies that promote healthy eating patterns, effective stress management techniques, and the reduction of exposure to pollution is strongly advised, particularly in urban and coastal regions. Further research is required to confirm these results. Such research should be conducted using a longitudinal approach.

Keywords: *Type 2 Diabetes Mellitus, Risk factors, Predictive Model, Lifestyle, Environment*

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1. INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a growing global health problem, with its prevalence increasing significantly worldwide. According to the International Diabetes Federation (IDF), in 2024, it is estimated that there will be approximately 589 million adults (aged 20–79 years) living with diabetes, and this number is predicted to increase to 853 million by 2050 [1]. In addition, according to the World Health Organization (WHO), approximately 830 million adults worldwide had diabetes in 2022, representing a significant increase from 200 million in 1990. The prevalence of diabetes

among adults has more than doubled, rising from 6.8% in 1990 to 14.1% in 2022, and more than half of these individuals remain undiagnosed or do not receive adequate treatment [2]. In Indonesia, diabetes is becoming an increasingly serious problem, with data from the 2018 Riskesdas survey showing a prevalence of type 2 diabetes mellitus (T2DM) diagnosed by doctors in people aged 15 years and older of 2%. This figure represents an increase compared to the 2013 Riskesdas survey, which recorded a prevalence of 1.5% [3]. Furthermore, the prevalence of diabetes in the early adult age group is increasing, becoming an important health issue, with the highest proportion at the young age group who have never measured their blood sugar levels [4]. In Riau Province, the prevalence of diabetes is also high, reaching 90,796 cases in 2023, with significant distribution in coastal and urban areas. Areas such as Dumai, Bengkalis, and Pekanbaru have recorded high incidence rates, which are important indicators for more effective health interventions [5].

Research on risk factors for type 2 diabetes mellitus (T2DM) in young adults (18–44 years) has identified several important areas requiring further attention. Previous studies have shown that low education is a significant risk factor for developing T2DM at a young age [6], however, more research is needed to develop education-based interventions to reduce this risk. Socioeconomic status is also a key determinant of T2DM risk, with minority groups and economically disadvantaged populations exhibiting higher incidence rates [7], [8]. Therefore, more research is needed to understand the mechanisms behind this phenomenon and develop more effective interventions. The influence of higher education and socioeconomic status on the risk of T2DM in early adulthood has not been well explored. Research often overlooks how educational attainment and socioeconomic factors may interact with other risk factors [9], [10].

In terms of behaviour and lifestyle, although physical inactivity and poor diet are known to be major risk factors, there is still limited data on effective lifestyle interventions specifically for early adulthood [11]. Further research in this area is essential, particularly regarding the effects of alcohol consumption and smoking, which have not been extensively studied in this age group [12]. In addition, genetic factors such as family history have also been proven to be significant predictors of T2DM [13], [14]. However, the extent to which these genetic factors interact with environmental factors and lifestyle in early adulthood remains to be fully elucidated. Conversely, metabolic and inflammatory markers, including insulin resistance and inflammation, have been identified as risk factors for T2DM [15], [16], however, further validation and exploration of these markers in the context of early adulthood is still needed.

Mental health factors also showed a strong association with incident T2DM among young adults, but further research is needed to understand how mental health interventions can reduce diabetes risk [7]. Furthermore, there is a necessity to explore gender differences in greater depth, as studies have demonstrated discrepancies in diabetes risk factors between men and women [7], [13].

In this study, the main objective was to analyse a predictive model of risk factors for type 2 diabetes mellitus in the early adult age group of coastal and urban communities in Riau Province. This research focuses on developing a prediction model that integrates environmental factors, lifestyle and individual characteristics to map the risk of T2DM in early adulthood. This offers innovation with a more comprehensive approach than previous studies that examined risk factors in isolation. This study also delves deeper into environmental factors such as air pollution, noise and night light exposure that have a significant influence on the risk of type 2 diabetes in early adulthood, especially in coastal and urban areas. Thus, this study provides new insights into the relationship between environmental factors and the risk of T2DM in younger age groups and opens up opportunities for more in-depth follow-up research. This study also focuses on the Riau Province region, with particular attention to its unique geographical and social characteristics and their impact on T2DM prevalence. This provides a novel contribution to public health research in Indonesia, particularly with a more contextualised neighbourhood-based approach.

2. METHOD

Study Design and Location

This study utilised a quantitative survey design and multivariate analysis using SmartPLS to explore the correlations and interactions between environmental exposures and Type 2 Diabetes Mellitus risk factors in the young adult population (18-45 years old). This approach was chosen for its ability to handle complex and multi-dimensional relationships between variables in the model. The study was conducted in six cities/districts in Riau Province: Pekanbaru, Dumai, Bengkalis, Pelalawan, Siak, and Rokan Hilir, which have the highest number of diabetes cases in early adulthood based on Riskesdas 2018 data. The study was conducted from June 2024 to December 2024.

Population and sample

The subjects of this study came from six locations in Riau Province recorded in the adult chronic disease data and epidemiological surveillance of the Riau Provincial Health Office in 2023. The sample size was calculated using the sample size calculation formula with a margin of error (E) of 3.48% and a confidence level of 95%, resulting in a total sample of 791 respondents. Sampling was conducted using the Simple Random Sampling method, where each district/city had the same opportunity to be selected as a respondent, according to the proportion of the subject population in each region.

Sample criteria

The inclusion criteria in this study were respondents who were between 18 and 45 years old and were permanent residents who had lived in Riau Province for more than 6 months prior to the survey. The exclusion criteria included women who were pregnant, individuals with coginitive impairments that could affect understanding of the research instruments, as well as individuals suffering from serious illness or disabilities that could affect research participation or results. In addition, individuals who refused to participate in the study were also excluded from the sample.

Sampling procedure and Data collection

The data collection process began with the identification of a representative sample of young adults aged 18 to 45 years. In the early stages of the study, data was collected on the respondents' demographic characteristics, health history, and environmental factors that may influence the risk of type 2 diabetes. Subsequently, periodic follow-ups were conducted to observe the development of health and environmental factors during the study period. The survey data was collected by developing a questionnaire covering environmental determinant variables such as diet, physical activity level, chemical exposure, stress, sleep patterns, and living environment. The survey was conducted through various methods, including in-person interviews, online surveys, and written questionnaires sent to respondents. Variable measurement was conducted by objectively and subjectively measuring the environmental determinant variables in accordance with the established operational definitions. This process ensures that the measurement instruments used have good validity and reliability to avoid data bias.

Research Variables

This study involves dependent and independent variables. The dependent variable is type 2 diabetes mellitus. The independent variables consisted of environmental determinants, lifestyle, consumption behaviour, and respondent characteristics. The dependent variable was type 2 diabetes, which was measured based on glucose intolerance, determined through a fasting blood sugar test or HbA1c, and categorised into diabetic or non-diabetic.

Determinants of consumption behaviour were measured based on dietary patterns and eating habits outside the home. Diet refers to the daily intake of nutrients including calories, saturated fat, sugar, fibre, and types of food consumed, while eating out reflects the behaviour of consuming food sold outside the home. Determinants of individual characteristics include obesity, abdominal obesity, economic status, and medical history. Obesity was measured using body mass index (BMI), while abdominal obesity was evaluated through waist circumference measurement. Economic status was calculated based on household income, while medical history included prediabetes, cholesterol levels, and blood pressure. Environmental determinants included physical, chemical, and social environments. The physical environment was measured by the availability of recreational facilities, health facilities, and public transport around the residence. The chemical environment refers to exposure to chemicals such as pesticides and air pollution. The social environment includes the influence of social information from social media and neighbourhoods on respondents' food consumption patterns. Lifestyle determinants include stress, sleep patterns, physical activity, and smoking and alcohol consumption. Stress was measured based on an individual's perception of life pressure, sleep patterns based on sleep duration and quality, physical activity based on frequency and duration of physical activities, and smoking and alcohol consumption based on their respective consumption levels.

Statistical Analysis

Data analysis was conducted using SPSS version 26 for descriptive statistics, while SmartPLS version 3.2.8 was used to test the influence between variables and build structural models. PLS-SEM analysis was conducted in several stages, including conceptual model development, construct measurement, and construct reliability and validity testing. Model estimation uses analysis schemes such as factorial and path analysis. Re-sampling is performed using bootstrapping to evaluate the stability of the estimates. The path diagram illustrates the relationship between latent constructs and indicators. Evaluation of the measurement model is done by testing convergent validity, discriminant validity, and composite reliability, with an expected AVE value of more than 0.5 and composite reliability of more than 0.7.

The structural model was evaluated using R-Square to assess the predictive power of the model, with criteria for R-Square values indicating a strong, moderate, or weak model. Evaluation is also done with Q^2 predictive relevance to measure the predictive ability of the model. Significance testing was conducted using bootstrapping with a t-value for a 5% significance level (1.96).

3. RESULTS

Respondent Characteristics

Table 1. Distribution of Respondents' Characteristics in Coastal and Urban Areas of Riau Province (n=791)

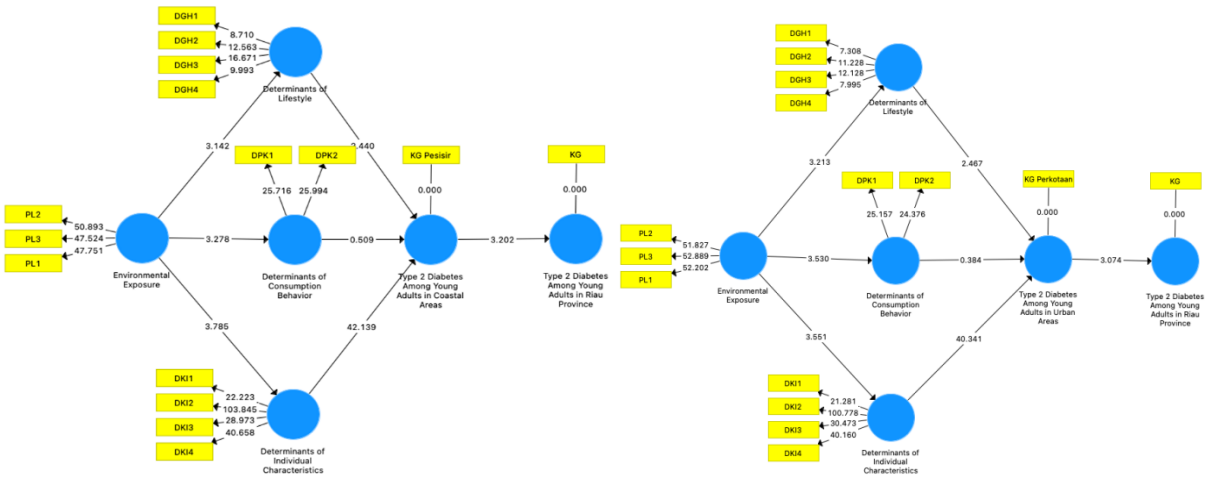
Characteristic	Coastal		Urban	
	n=396	%	n=396	%
Age				
18-25 years	28	7.0	47	11.9
26-35 years	83	21.0	73	18.4
36-45 years	285	72.0	276	69.7
Gender				
Male	138	34.8	130	32.8
Female	258	65.2	266	67.2
Education				
Elementary School	2	0.5	1	0.3
Junior High School	118	29.8	102	25.8
Senior High School	194	49.0	208	52.5
Higher Education	2	0.5	57	14.4
No Formal Education	31	7.8	28	7.1
Occupation				
Housewife	194	49.0	209	52.8
Government Employee	27	6.8	40	15.2
Farmer/Fisherman	26	6.6	41	10.4
Entrepreneur	128	32.3	60	15.2
Unemployed	11	2.8	19	4.8
Other	10	2.5	27	6.8
Total	**396**	**100**	**396**	**100**

Table 1 presents the demographic characteristics of respondents from coastal (n = 396) and urban (n = 396) areas of Riau Province. The majority of respondents in both areas are aged 36–45 years (72.0% in coastal, 69.7% in urban areas). Female respondents represent a higher proportion in both areas (65.2% in coastal, 67.2% in urban). Most respondents have completed senior high school (49.0% in coastal, 52.5% in urban), followed by junior high school. Notably, a larger percentage of respondents in urban areas have attained higher education (14.4%) compared to those in coastal areas (0.5%). In terms of occupation, housewives dominate in both regions (49.0% in coastal, 52.8% in urban). Coastal respondents are more likely to be entrepreneurs (32.3%), while urban respondents show a more diverse distribution, including a higher proportion of government employees (15.2%) and those in the “other” category (6.8%)..

Table 2. Results of the inner test of the Prediction Model for Type 2 Diabetes Mellitus Risk Factors in the Early Adult Age Group with an Environmental Approach in Coastal and Urban Communities

Variables	Coastal			Urban		
	R Square	Adjusted R Square	Q²	R Square	Adjusted R Square	Q²
Determinants of Lifestyle	0,028	0,025	0,017	0,028	0,025	0,016
Determinants of Individual Characteristics	0,036	0,033	0,020	0,035	0,033	0,020
Determinants of Consumption Behavior	0,029	0,027	0,020	0,030	0,028	0,020
Type 2 diabetes in early adult age group (in Riau Province)	0,026	0,023	0,023	0,025	0,022	0,022
Coastal Type 2 Diabetes	0,631	0,628	0,621			
Urban Type 2 Diabetes				0,627	0,625	0,617

Table 2 presents the results of the inner model test using R Square, Adjusted R Square, and Q² (predictive relevance) values to assess the predictive ability of risk factors for Type 2 Diabetes Mellitus (Type 2 DM) in the early adult age group in Riau Province, based on a comparison between coastal and urban areas. The R Square and Q² values of the determinant variables of lifestyle, individual characteristics, and consumption behavior showed predictive ability although with relatively low values (e.g. R^2 between 0.025-0.036). The test results showed that there was a statistically significant influence on Type 2 DM in coastal areas, indicated by an R^2 value of 0.631 and Q^2 of 0.621. Meanwhile, the prediction for urban areas was also quite high ($R^2 = 0.627$; $Q^2 = 0.617$), although some determinant variables did not show significant influence (e.g. lifestyle and individual characteristics with P = 0.050 and P = 0.356). These findings indicate that environmental approaches influence Type 2 DM risk differently depending on the geographical and social context of coastal and urban areas. The prediction model in coastal areas performed very well, while the model in urban areas requires further evaluation, especially regarding the role of individual determinants and lifestyle.



Coastal **Urban**

Figure 2. Bootstrapping Test Results on Coastal and Urban Areas

Figure 2 shows that in coastal areas, the environmental exposure influence pathway showed strong coefficient values on consumption behavior (β = 3.354), individual characteristics (β = 4.371), and lifestyle (β = 3.905). Consumption behavior was shown to have a direct effect on Type 2 DM (β = 0.374), while the direct effects of lifestyle and individual characteristics were not significant. This indicates that in coastal contexts, consumption patterns are the main pathway

bridging environmental impacts to Type 2 DM risk.

Meanwhile, in urban areas, environmental exposure also influenced the three main determinants with more moderate values (lifestyle β = 2.703; consumption behavior β = 3.145; individual characteristics β = 2.715). However, in contrast to coastal areas, here the determinants of lifestyle (β = 2.770) and individual characteristics (β = 2.159) showed a significant direct influence on Type 2 DM risk. This suggests that in urban populations, the risk of Type 2 DM is more influenced by lifestyle factors and individual characteristics directly, rather than through consumption behavior.

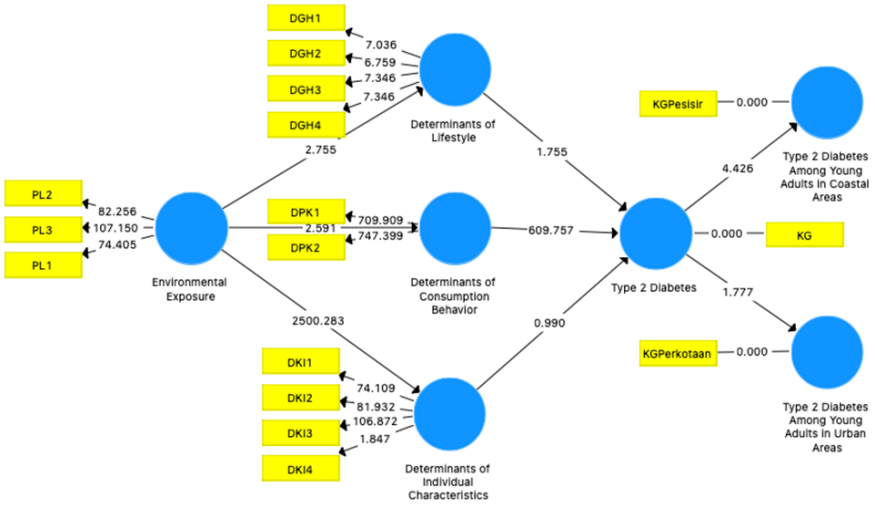


Figure 1 Model of the Influence of Environmental Determinants, Lifestyle, Consumption Behaviour, Individual Characteristics on Type 2 Diabetes Mellitus in Coastal and Urban Areas

Figure 1 shows the model of the influence of environmental determinants, lifestyle, consumption behaviour, and individual characteristics on Type 2 Diabetes Mellitus in coastal and urban areas. Based on this figure, the mean value of each variable indicator is known, where the lowest mean value is found in the Individual Characteristics Determinant indicator with an average of 1.920 on the indicator (DKI1) Disease History. Meanwhile, the lowest mean value in the Determinants of Lifestyle was found in the indicator (DGH1) Smoking and Alcohol Consumption, with an average value of 8.080.

DISCUSSION

This study found a significant association between consumption behaviour and the risk of type 2 diabetes in early adulthood. This finding is in line with previous studies that have found that consumption of sugary foods increases the risk of diabetes in younger age groups [17], [18], [19]. However, consumption of fatty foods did not show a significant association with the risk of type 2 diabetes in early adulthood, which is in line with the findings of previous studies [20], [21]. However, this result contradicts the results of other studies which suggest that consumption of fatty foods is positively associated with an increased risk of type 2 diabetes [20], while a meta-analysis study that stated replacing saturated fat with unsaturated fat or carbohydrates can reduce the incidence of cardiovascular disease in people with type 2 diabetes, which showed a significant association between dietary fat and the risk of diabetes-related diseases [22]. This discrepancy in findings may be attributable to methodological differences or other influencing factors that have not been comprehensively controlled for in this study.

Physiologically, consumption of sugary drinks contributes to increased inflammation and impaired glucose metabolism, which worsens insulin resistance [23]. This is in line with studies showing that consumption of fructose, found in sweetened beverages, can worsen inflammation, and increase the risk of diabetes even in people without a history of obesity [24]. This study also supports findings that a plant-based diet, which is low in energy density, can reduce the risk of type 2 diabetes, in contrast to a high-energy diet, which actually increases the risk of this disease [25]. In addition, high saturated fat consumption also shows a significant association with an increased risk of type 2 diabetes in several recent meta-analyses, supporting the hypothesis that a diet rich in saturated fat has the potential to affect insulin sensitivity and glucose metabolism in the body [22], [26].

This study can also be linked to the Health Belief Model, which states that changes in consumption behaviour are influenced by individuals' perceptions of the risks of disease and the benefits of such changes. According to this model, individuals who are aware of the potential risks of diseases such as diabetes tend to change their eating behaviour [27]. Therefore, our findings regarding sweet food consumption being associated with an increased risk of type 2 diabetes are consistent with this theory, in which individuals who are aware of their risk of diabetes tend to reduce their consumption of sweet foods. Conversely, high saturated fat consumption is associated with increased insulin resistance, which is supported by the

Metabolic Disruption Theory, which states that a high-fat diet can worsen insulin resistance and glucose metabolism disorders [28].

The findings of this study also reveal that environmental exposures, such as noise and night- time lighting, have a significant influence on the increased risk of diabetes in young adults. High exposure to noise and night-time lighting contributes to sleep disturbance, which in turn can increase the risk of diabetes. A meta-analysis shows that shorter sleep duration increases the risk of diabetes by 9% [29]. In addition, air pollution, particularly fine particles such as PM2.5, has been shown to have a significant long-term impact on increasing the risk of type 2 diabetes, with studies revealing a link between PM2.5 exposure and glucose metabolism disorders [30], [31], [32].

PM2.5 exposure affects endothelial function and increases insulin resistance, which plays a role in the development of type 2 diabetes. Other studies have shown that exposure to air pollution increases the risk of microvascular complications in patients with type 2 diabetes [33], [34], [35]. Although not invariably causal, extant evidence suggests that long-term exposure to air pollution interacts with other factors, such as diet and lifestyle, that exacerbate the predisposition to type 2 diabetes. In urban areas, elevated levels of air pollution have been demonstrated to be associated with an increased prevalence of diabetes, particularly among individuals who are exposed to such conditions for extended periods and with greater frequency [36].

The present study revealed an absence of a statistically significant relationship between lifestyle factors (e.g., stress, sleep patterns, physical activity, smoking habits, and alcohol consumption) and the risk of type 2 diabetes in respondents residing in coastal and urban areas. As demonstrated in numerous preceding studies, young adults suffering from type 2 diabetes and experiencing complications exhibit a higher level of psychological stress in comparison to their middle-aged and older counterparts [37]. This indicates a link between ongoing stress and an increased risk of diabetes, particularly among younger people. In addition, shorter sleep duration, less than 7–8 hours, has been shown to increase the risk of type 2 diabetes by up to 9%, and sleep restriction for five days can reduce insulin sensitivity by up to 29% [25]. Sleep disorders and high psychosocial stress, as described in the Metabolic Disruption Theory, can worsen glucose metabolism and increase insulin resistance, which in turn increases the risk of type 2 diabetes [28]. Further research also shows that sleep disturbances caused by psychosocial stress, as well as irregular sleep patterns, further exacerbate insulin sensitivity and other metabolic disorders, which increase the risk of further diabetes [38], [39].

Furthermore, metabolic disorders associated with circadian rhythm disruption represent significant factors in the development of diabetes. Discrepancies between sleep patterns and the body's metabolic rhythms have been demonstrated to exacerbate insulin resistance and influence the body's glucose regulation [28]. It has been demonstrated by other studies that a well-regulated circadian rhythm is imperative for the effective regulation of the body's metabolism, particularly with regard to the management of glucose levels. A failure of synchrony between sleep cycles and metabolic cycles, which are ordinarily established during the diurnal and nocturnal periods, respectively, has the potential to result in elevated blood glucose levels and an increased risk of developing insulin resistance. This, in turn, can be a major contributing factor to the onset of type 2 diabetes [40].

Low physical activity, such as sitting around, can cause fat and sugar to accumulate in the body, which ultimately increases blood glucose levels [41]. Conversely, more strenuous physical activity increases insulin sensitivity and helps control blood glucose levels, with insulin sensitivity increasing by up to 15% in individuals who engage in moderate to strenuous physical activity [42]. In addition, smoking among people aged over 20 increases the risk of diabetes by 3.25 times, and smoking directly contributes to insulin resistance through reduced glucose absorption [43]. However, overall, the results of this study indicate that lifestyle factors play a role as determinants of diabetes risk in the long term, and the short-term adverse effects of lifestyle are not sufficient to develop diabetes without other determining factors.

Individual characteristics, such as body mass index (BMI), economic status, and medical history, did not show a significant association with diabetes risk in the study participants, according to the results of this study. However, visceral obesity (abdominal obesity) detected by a waist circumference of more than 100 cm^2 was strongly associated with an increased risk of type 2 diabetes. Previous studies have shown that an increase in BMI from 22 to 27 can increase the risk of diabetes by approximately threefold [44], and abdominal obesity plays a greater role in this increase. However, economic status and health history among the respondents in this study did not show a significant effect on diabetes risk, which may be due to other factors such as diet, lifestyle, and genetic factors. Higher income is not always associated with increased consumption of risky foods, so it does not affect diabetes risk in individuals with normal BMI, but it does affect those with more dangerous visceral fat accumulation for metabolic health. Previous studies have shown that lower socioeconomic factors are more likely to be associated with unhealthy lifestyles, such as high-calorie diets and low physical activity, which increase diabetes risk [45], [46].

The strength of this study lies in its multivariate approach to identifying complex relationships between environmental determinants, lifestyle, and consumption behaviour in relation to the risk of type 2 diabetes, as well as the application of a predictive model that can be used to inform health policies at the provincial level. This study also has a fairly representative population of young adults in coastal and urban areas, with systematic data collection through surveys. However, the limitations of this study include the use of cross-sectional data, which limits understanding of causality, as well as potential

information bias caused by reliance on self-report in measuring lifestyle and consumption behaviour. Additionally, although the study sample is sufficiently large, there is a possibility of variability in individual characteristics that cannot be fully controlled, which may affect the generalisability of findings to a broader population.

4. CONCLUSION

The present study successfully identified and analysed the main risk factors associated with type 2 diabetes in young adults in coastal and urban areas of Riau Province. The findings indicate that consumption of sugary foods and environmental factors, such as noise and air pollution, play a significant role in increasing the risk of diabetes. Despite the absence of a statistically significant association between the consumption of high-fat food and the development of the condition, abdominal obesity remains the primary risk factor. It is recommended that policies be developed which promote the consumption of a plant-based diet and manage environmental risk factors, with a particular focus on urban and coastal areas. Moreover, longitudinal studies are required with a high degree of urgency in order to enhance comprehension of the causal relationships among these factors and to refine diabetes risk prediction models for young adults.

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