

NUTRITIONAL KNOWLEDGE, GENETICS, OBESITY, AND EDUCATION: RISK FACTORS FOR TYPE 2 DIABETES AT SARANPANDANG

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Abstract

Type 2 Diabetes Mellitus (T2DM) represents a persistent global public health challenge, particularly in low and middle income countries where early detection and preventive efforts remain limited. This study aims to examine the associations between nutritional knowledge, genetic predisposition, nutritional status, and educational attainment with the risk of T2DM among adults residing in the service area of Puskesmas Saranpadang, Kabupaten Simalungun. Employing an analytical cross-sectional design, the study involved 94 adults aged 45–55 years selected through purposive sampling. Nutritional knowledge was evaluated using a standardized and validated questionnaire, while random blood glucose levels (RBGL) were measured to identify individuals at risk, with RBGL ≥ 200 mg/dL classified as “at risk.” Data were analyzed using the Chi-square test, with statistical significance determined at P -value < 0.05 . The results demonstrated significant associations between T2DM risk and educational level (P -value = 0.003), nutritional knowledge (P -value = 0.001), genetic history (P -value = 0.001), and nutritional status based on body mass index (P -value = 0.001). Participants with limited nutritional knowledge, positive familial diabetes history, and elevated BMI exhibited a higher likelihood of being at risk for T2DM. Lower educational attainment was further associated with reduced health literacy and suboptimal lifestyle practices. The novelty of this study lies in its comprehensive analysis of multiple interacting risk factors using RBGL screening within a primary healthcare context. These findings underscore the importance of strengthening community-based prevention strategies, particularly through targeted health education and early screening programs, to mitigate the rising burden of T2DM in resource-limited settings.

Keywords: Education; Genetics; Nutritional knowledge; Obesity; Type 2 Diabetes Mellitus.

INTRODUCTION

Health is a state of physical, mental, spiritual, and social well-being that enables individuals to lead productive and meaningful lives, as specified in Law Number 36 of 2009 on Health. Within the human life cycle, adulthood to older age represents a period of heightened vulnerability to various diseases, particularly chronic non-communicable diseases. As individuals age, physiological, metabolic, cognitive, and emotional

changes occur, leading to a gradual decline in cellular and tissue function and increasing susceptibility to health disorders (1,2). This also puts the elderly at risk of developing degenerative diseases, health conditions that occur due to the deterioration of tissue or organs over time (3). This condition explains why individuals aged 45 years and older face a higher risk of developing chronic diseases such as hypertension, cardiovascular

disease, metabolic disorders, and diabetes mellitus (4–6).

Diabetes mellitus (DM) is one of the chronic non-communicable diseases that remains a major global health problem (7,8). DM is characterized by increased sugar accompanied by disturbances in protein, carbohydrate and lipid metabolism (9). DM is defined as a metabolic syndrome characterized by disturbances in carbohydrate, fat, and protein metabolism resulting from impaired insulin secretion, impaired insulin action, or a combination of both (10–12). Based on the cause, Diabetes Mellitus is classified into 3 groups/types, including Type II Diabetes Mellitus, Type II Diabetes Mellitus and Gestational Diabetes (13). However, in general DM is classified into two main types, namely type 1 diabetes mellitus and type 2 diabetes mellitus. Type 2 diabetes mellitus is the most prevalent form and typically occurs in adulthood and older age. In this condition, basal insulin secretion may be normal or decreased; however, the insulin response to elevated blood glucose levels is delayed or inadequate, often exacerbated by insulin resistance in target tissues (14–16).

Diabetes mellitus is the sixth leading cause of death in the world (17).

Epidemiology shows an increasing trend in the incidence and prevalence of type 2 diabetes worldwide. The WHO estimates that the total number of cases of type 2 diabetes could rise sharply in the coming years (18). Globally, diabetes continues to represent a growing public health burden. It is estimated that approximately 589 million adults aged 20–79 years are currently living with diabetes worldwide. This number is projected to increase substantially, reaching an estimated 853 million individuals by 2050. Notably, more than four out of five adults with diabetes (81%) live in low- and middle-income countries, highlighting the disproportionate impact of the disease on populations with limited healthcare resources. This trend underscores diabetes as a critical global health challenge, particularly for countries with developing health systems, where early detection and effective preventive strategies remain essential. This situation positions diabetes as one of the major challenges facing the national healthcare system (19).

Indonesia itself is ranked seventh in the world with the highest number of people with diabetes (20). At the regional level, North Sumatra Province is among the areas with a relatively high prevalence of

diabetes. Data indicates that Simalungun Regency ranks fourth in the province in terms of the number of diabetes cases, with individuals aged 55–74 years identified as the most vulnerable group (21). The increasing prevalence of Type 2 Diabetes Mellitus not only affects individuals' quality of life but also imposes substantial economic and social burdens on families and the healthcare system.

Risk factors that can cause diabetes are divided into two, namely non-modifiable factors and modifiable factors (22). Numerous studies have demonstrated that Type 2 Diabetes Mellitus (T2DM) is a multifactorial disease influenced by a combination of biological, behavioral, and social determinants, including nutritional knowledge, genetic factors, obesity, and educational attainment. Lifestyle, diet, work environment, exercise and stress can cause health problems (23). Studies by (24) indicate that low nutritional knowledge is associated with poor dietary management and an increased risk of diabetes. In addition, studies by (25), (26), and (27) state that family history/genetics of diabetes is known to increase individual susceptibility to impaired glucose regulation due to hereditary factors that

affect insulin sensitivity. Obesity also contributes significantly to the risk of T2DM through mechanisms involving increased insulin resistance and disrupted glucose metabolism (29–31). Other studies (32–34) have shown that educational attainment influences an individual's ability to access, understand, and apply health-related information, including preventive measures for non-communicable diseases such as T2DM.

The research gap addressed in this study lies in the fact that most existing studies focus on single risk factors associated with Type 2 Diabetes Mellitus. This study seeks to fill that gap by simultaneously examining multiple risk factors influencing T2DM. Furthermore, the use of random blood glucose level (RBGL) measurement as an indicator of T2DM risk within the context of primary healthcare services has not been extensively explored.

The Saranpadang Primary Health Center, which serves 14 villages with a substantial adult population, represents a strategic setting for the early, community-based identification of T2DM risk factors. A thorough understanding of local risk factors is expected to provide a foundation

for developing more effective and targeted promotional and preventive interventions.

The novelty of this study lies in its comprehensive approach to assessing the risk of Type 2 Diabetes Mellitus by integrating nutritional knowledge, genetic history, nutritional status (body mass index), and educational attainment simultaneously among an adult population at the primary healthcare level.

This study aims to analyze the associations between nutritional knowledge, genetic history, nutritional status, and educational attainment and the risk of Type 2 Diabetes Mellitus among adults in the service area of the Saranpadang Primary Health Center, Simalungun Regency. The findings are expected to contribute scientifically to the development of community-based T2DM prevention strategies and to serve as a reference for healthcare providers in strengthening education and early detection efforts for diabetes mellitus in primary healthcare settings.

RESEARCH METHODS

This study employed an analytical cross-sectional design to examine the association between nutritional knowledge and the risk of Type 2 Diabetes Mellitus

among adults aged 45–54 years at the Saranpadang Health Center, Simalungun Regency, Indonesia, during August–September 2024. A total of 94 participants were selected using purposive sampling, with inclusion criteria. Nutritional knowledge was measured using a standardized questionnaire, while the risk of Type 2 DM was assessed using Random Blood Glucose Level (RBGL); values ≥ 200 mg/dL were categorized as “at risk” and < 200 mg/dL as “not at risk,” given RBGL's practicality for primary-care screening and field data collection. The relationship between nutritional knowledge and Type 2 DM risk was analyzed using the Chi-square test with a significance level of $p < 0.05$ in SPSS version 25, without multivariate modeling due to limited sample size and unbalanced category distributions. The study obtained ethical approval from the Research Ethics Committee of the Faculty of Medicine, University of North Sumatra (No. 933/KEPK/USU/2024), and all respondents provided.

RESULTS AND DISCUSSION

Result

This study was conducted in the working area of Saranpadang Health

Center, Dolok Silau District , Simalungun Regency. The health center serves 14 villages. The research subjects were adults aged 45–55 living in the Saranpadang Health Center area, with a total of 94 participants. The characteristics of the

study subjects are presented in Table 1. Factors Associated with the Risk of Type 2 Diabetes Mellitus Among Adults in the Saranpadang Health Center Area, Simalungun Regency are presented in Table 2.

Table 1. Characteristics of Participants

Variables		Frequency	%
Age (years)	45-50	66	70.2
	51-55	28	29.8
Sex	Female	69	73.4
	Male	25	26.6
Income Level	Below Regional Minimum Rage	38	40.4
	Above Regional Minimum Rage	56	59.6
Highest Educational Level	Elementary School	11	11.7
	Junior High School	16	17
	Senior High School	37	39.4
	Diploma	9	9.6
	Bachelor	21	22.3
Employment Status	Yes	2	2.1
	No	92	97.9

Source: Primary Data, 2025

Based on Table 1, the majority of respondents were aged 45–50 years (70.2%), while the remaining participants were aged 51–55 years (29.8%), indicating that most participants were in the early older adult age group at risk of diabetes. The gender distribution was dominated by females (73.4%), reflecting greater female representation in this study. From a socioeconomic perspective, more than half of the respondents had an income above the Regional Minimum Wage (59.6%), whereas 40.4% earned below the minimum

wage. The highest proportion of respondents had completed senior high school education (39.4%), followed by bachelor's degree holders (22.3%) and junior high school graduates (17%), while a smaller proportion had only elementary education. Nearly all respondents were not formally employed (97.9%), reflecting the characteristics of the adult population in the Saranpadang Primary Health Center service area, where non-formal activities or household work predominated.

Table 2. Factors Associated with Type 2 Diabetes Mellitus Among Adults in Saranpadang Health Center, Simalungun Regency

Variables		RBGL		P-value
		DM Risk	No risk	
Highest Educational Level	Elementary School	6	5	0.003
	Junior High School	12	4	
	Senior High School	16	21	
	Diploma	1	8	
	Bachelor	4	17	
Nutritional Knowledge	Low	26	3	0.001
	Medium	12	20	
	High	1	32	
Genetic History	Yes	4	27	0.001
	No	35	28	
Nutritional Status	Underweight	9	0	0.001
	Normal	2	16	
	Overweight	7	15	
	Obesity I	11	33	
	Obesity II	10	19	
Total		39	55	

Source: Primary Data, 2025

Based on Table 2, the analysis results indicate significant associations between several factors and the risk of Type 2 Diabetes Mellitus among respondents. Educational attainment was significantly associated with diabetes risk ($p = 0.003$), as evidenced by a higher proportion of at-risk individuals among those with lower education levels. Nutritional knowledge also showed a highly significant association with diabetes risk ($p = 0.001$), with the highest risk observed among respondents with low nutritional knowledge. In addition, a genetic history of diabetes was significantly associated with the risk of Type 2 Diabetes Mellitus ($p = 0.001$), as respondents with a family history of

diabetes were more likely to be in the at-risk group. Nutritional status based on body mass index also demonstrated a significant association with diabetes risk ($p = 0.001$), with the proportion of at-risk individuals increasing alongside higher BMI categories, particularly among obese respondents. These findings indicate that educational attainment, nutritional knowledge, genetic history, and nutritional status are significantly associated with the risk of Type 2 Diabetes Mellitus in the adult population within the Saranpadang Primary Health Center service area.

Discussion

Relationship Between Nutritional Knowledge and the Risk of Type 2 Diabetes Mellitus

The significant association between the level of nutritional knowledge and the risk of Type 2 Diabetes Mellitus identified in this study indicates that nutritional knowledge plays an important role in shaping individual health behaviors. Inappropriate food choices and portion sizes, such as high consumption of simple sugars and saturated fats and low fiber intake, can trigger chronic increases in blood glucose levels, ultimately leading to insulin resistance. Individuals with low nutritional knowledge tend to have a limited understanding of balanced dietary principles and portion control, making them more susceptible to impaired glucose metabolism. This condition is further exacerbated by limited access to easily understandable and continuous health information, particularly in rural areas such as the service area of the Saranpadang Primary Health Center. Nutritional education that has not been optimally integrated into daily community life may result in a gap between available information and actual practices in the

field. These findings are consistent with the study by Karkhah et al. (2024), which reported that low nutritional knowledge is associated with suboptimal dietary management, including high intake of sugar and fat and low fiber consumption, contributing to impaired glucose regulation. The consistency of these results strengthens the evidence that nutritional knowledge is a key determinant in the prevention of Type 2 Diabetes Mellitus, particularly through dietary behaviors that directly affect glucose metabolism.

Relationship Between Genetic History and the Risk of Type 2 Diabetes Mellitus

The finding that genetic history is significantly associated with the risk of Type 2 Diabetes Mellitus underscores the role of hereditary biological factors in the pathogenesis of this disease. Genetically, individuals with a family history of diabetes tend to have impaired insulin sensitivity and β -cell dysfunction due to variations in specific genes, such as *TCF7L2* and *PPARG*. This condition increases susceptibility to hyperglycemia even when exposure to environmental risk factors is relatively similar. These findings are consistent with studies by (36,37), which emphasize that hereditary factors play a

crucial role in insulin sensitivity impairment and β -cell dysfunction. The consistency of these results indicates that genetic predisposition represents a relatively stable and universal risk factor across different populations.

However, this study highlights that genetic influence does not operate in isolation but rather interacts with environmental and social factors. Family lifestyles are often transmitted across generations, and household environments characterized by high sugar and fat consumption and low levels of physical activity may amplify the expression of genetic risk. Consequently, the elevated risk of diabetes among individuals with a family history of the disease reflects a complex interaction between biological and social factors that mutually reinforce one another. This finding extends previous research by emphasizing the importance of preventive approaches that address not only biological susceptibility but also behavioral modifications within the family environment.

Relationship Between Nutritional Status (BMI) and the Risk of Type 2 Diabetes Mellitus

The results of this study demonstrate a significant association between nutritional status and the risk of Type 2 Diabetes Mellitus. Excess accumulation of adipose tissue increases the release of proinflammatory cytokines such as TNF- α and IL-6, which impair insulin sensitivity in peripheral tissues. This condition forces the pancreas to increase insulin production as a compensatory response, which over time may lead to β -cell exhaustion and dysfunction, ultimately resulting in chronic hyperglycemia. The higher prevalence of excess nutritional status among respondents is likely influenced by changes in dietary patterns and lifestyle behaviors. Although most respondents are not formally employed and still engage in daily physical activities, high-energy dietary intake that is not accompanied by proper nutritional management may represent a dominant contributing factor. These findings are consistent with studies by (38–40), which explain that obesity increases diabetes risk through mechanisms involving increased insulin resistance and chronic inflammation due to adipose tissue accumulation. The

consistency of these findings reinforces the biological evidence that obesity is a major risk factor for Type 2 Diabetes Mellitus across various population settings.

Relationship Between Educational Attainment and the Risk of Type 2 Diabetes Mellitus

This study found that educational attainment was significantly associated with the risk of Type 2 Diabetes Mellitus, with respondents who had lower levels of education exhibiting a higher risk. Individuals with lower educational attainment tend to have limited capacity to understand health-related information, including diabetes prevention, dietary management, and the importance of physical activity. These limitations may lead to lower adoption of healthy lifestyle behaviors, which in turn increases the risk of impaired glucose metabolism.

These findings are consistent with studies by (41,42), which report that education plays a crucial role in enhancing health literacy, enabling individuals to access, understand, and apply health information effectively in daily life, thereby contributing to the prevention of Type 2 Diabetes Mellitus.

CONCLUSION AND RECOMMENDATION

This study reveals key factors linked to the risk of Type 2 Diabetes Mellitus (DM). We found that poor nutritional knowledge, a family history of DM, a high Body Mass Index (BMI), and lower educational attainment significantly increased an individual's risk. These findings highlight the critical need for preventive strategies, such as nutrition education, early genetic screening, and promoting healthy lifestyles. Implementing these approaches could significantly reduce Type 2 DM prevalence, especially in high-risk groups, by improving community awareness about health management.

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REFERENCES

1. Ahmad E, Lim S, Lamptey R, Webb DR, Davies MJ. Type 2 diabetes. *The Lancet*. 2022 Nov;400(10365):1803–20.
2. Williams PC, Alhasan DM, Gaston SA, Henderson KL, Braxton Jackson W, Jackson CL. Perceived

- neighborhood social cohesion and type 2 diabetes mellitus by age, sex/gender, and race/ethnicity in the United States. *Prev Med (Baltim)*. 2023;170:107477.
3. Madania, Bangol A, Diantika A. Analisis Efektifitas Biaya Terapi Pada Pasien Hipertensi Dan Diabetes Melitus Tipe 2 Di Instalansi Rawat Jalan RSUD Toto Kabila. *Jambura Journal of Health Sciences and Research*. 2022;4(1):426–42.
 4. Rashmi R, Mohanty SK. Examining chronic disease onset across varying age groups of Indian adults using competing risk analysis. *Sci Rep*. 2023;13(1):5848.
 5. Cortez BN, Pan H, Hinthorn S, Sun H, Neretti N, Gloyn AL, et al. Heterogeneity of increased biological age in type 2 diabetes correlates with differential tissue DNA methylation, biological variables, and pharmacological treatments. *Geroscience*. 2024;46(2):2441–61.
 6. Misra S, Ke C, Srinivasan S, Goyal A, Nyriyenda MJ, Florez JC, et al. Current insights and emerging trends in early-onset type 2 diabetes. *Lancet Diabetes Endocrinol*. 2023 Oct;11(10):768–82.
 7. Khunti K, Chudasama Y V, Gregg EW, Kamkuemah M, Misra S, Suls J, et al. Diabetes and Multiple Long-term Conditions: A Review of Our Current Global Health Challenge. *Diabetes Care*. 2023 Nov;46(12):2092–101.
 8. Yameny AA. Diabetes mellitus overview 2024. *Journal of Bioscience and Applied Research*. 2024;10(3):641–5.
 9. Saptaningtyas R, Wahyuhendra R, Isworo JT. Hubungan Gula Darah puasa dengan Kolesterol LDL pada Pasien Diabetes Mellitus Tipe 2 di RSUD William Booth Kota Semarang. *Jambura Journal of Health Sciences and Research*. 2022;4(3):604–8.
 10. Jadon AS, Kaushik MP, Anitha K, Bhatt S, Bhadauriya P, Sharma M. Chapter 1 - Types of diabetes mellitus, mechanism of insulin resistance and associated complications. In: Tripathi P, Tripathi RP, Kaushik MPBTBI of D and AC, editors. Academic Press; 2024. p. 1–18.
 11. Venyo AKG. Diabetes mellitus: a review and update. *Journal of*

- Ophthalmology Research Reviews & Reports. 2023;4(4):1–24.
12. Powers AC, Niswender KD, Evansmolina C. Mellitus : 415 Diabetes Diagnosis, Classification, and Pathophysiology.
 13. Hidayat AN, L TA, Siwi K. Evaluasi Rasionalitas Obat Antidiabetes Oral Terhadap Efektivitas Terapi Pasien Diabetes Melitus Tipe Ii RSUD Dr. Moewardi Surakarta. Jambura Journal of Health Sciences and Research. 2023;5(3):815–24.
 14. Hall JE, Hall ME. Guyton and Hall Textbook of Medical Physiology E-Book: Guyton and Hall Textbook of Medical Physiology E-Book. Elsevier Health Sciences; 2020.
 15. Chandrasekaran P, Weiskirchen R. The Role of Obesity in Type 2 Diabetes Mellitus—An Overview. Vol. 25, International Journal of Molecular Sciences. 2024. p. 1882.
 16. Lu X, Xie Q, Pan X, Zhang R, Zhang X, Peng G, et al. Type 2 diabetes mellitus in adults: pathogenesis, prevention and therapy. Signal Transduct Target Ther. 2024;9(1):262.
 17. Lee V, Nasution SW, Fadillah Q. Correlation of Proteinuria and Glucosuria Levels in Type 2 Diabetes Mellitus in Kampung Klumpang, North Sumatra. Jambura Journal of Health Sciences and Research. 2024;6(4):519–27.
 18. Michille, Situmorang S, Hanida W. Hubungan Karakteristik Pasien Diabetes Melitus Tipe 2 Dengan Lipid Profile Di RS Royal Prima Tahun 2021 Relationship Characteristics of Type 2 Diabetes Mellitus Patients With Lipid Profile At Royal Prima Hospital in 2021. Jambura Journal of Health Science and Research. 2022;5(1):42–50.
 19. IDF. International Diabetes Federation. 2024. Diabetes around the world in 2024.
 20. Mukti AW, Sari DP, Hardani PT, Rahayu A, Hidayatunnikmah N, Sastyarina Y, et al. Profil Prediabetes pada Usia Produktif. Jambura Journal of Health Science and Research. 2023;5(1):355–61.
 21. Milita F, Handayani S, Setiaji B. Kejadian diabetes mellitus tipe II pada lanjut usia di Indonesia (analisis

- riskeddas 2018). *Jurnal Kedokteran dan kesehatan*. 2021;17(1):9–20.
22. Novitasari DI. Characteristics of Patients With Diabetes Mellitus Type 2 That Was Hospitalized in Patar Asih Hospital Deli Serdang Regency. *Jambura Journal of Health Sciences and Research*. 2022;4(3):677–90.
 23. Setyawati T, Adawiyah R, Hijriani IN, Larasati RD. Edukasi Diet Dan Olahraga Dalam Menurunkan Kadar Glukosa Pasien Diabetes Melitus Diet and Exercise Education in Reducing Glucose Levels. *Jambura Journal Of Health Science And Research*. 2023;1166–74.
 24. Karkhah MR, Arasteh M TP. Nutritional knowledge and related factors among patients with diabetes mellitus: A systematic review. *J Nurs Reports Clin Pract*. 2024;3(1):69–77.
 25. Goyal S, Rani J, Bhat MA V V. Genetics of diabetes. *World J Diabetes*. 2023;6(14).
 26. Laakso M FSL. Genetics of Type 2 Diabetes: Past, Present, and Future. *Nutrients*. 2022;14.
 27. Shojima N YT. Progress in genetics of type 2 diabetes and diabetic complications. *J Diabetes Investig*. 2023;4(14).
 28. Shojima N, Yamauchi T. Progress in genetics of type 2 diabetes and diabetic complications. *J Diabetes Investig*. 2023 Apr;14(4):503–15.
 29. Klein S, Gastaldelli A, Yki-Järvinen H, Scherer PE. Why does obesity cause diabetes? *Cell Metab*. 2022 Jan;34(1):11–20.
 30. Yu H jie, Ho M, Liu X, Yang J, Chau PH, Fong DYT. Association of weight status and the risks of diabetes in adults: a systematic review and meta-analysis of prospective cohort studies. *Int J Obes*. 2022;46(6):1101–13.
 31. Yashi K, Daley SF. Obesity and type 2 diabetes. In: *StatPearls [Internet]*. StatPearls Publishing; 2023.
 32. Liao YS, Tsai WC, Chiu LT, Kung PT. Educational attainment affects the diagnostic time in type 2 diabetes mellitus and the mortality risk of those enrolled in the diabetes pay-for-performance program. *Health Policy (New York)*. 2023;138:104917.
 33. Zhang J, Chen Z, Pärna K, van Zon SKR, Snieder H, Thio CHL. Mediators of the association between educational attainment and type 2

- diabetes mellitus: a two-step multivariable Mendelian randomisation study. *Diabetologia*. 2022;65(8):1364–74.
34. Choi JY, Choi D, Mehta NK, Ali MK, Patel SA. Diabetes Disparities in the United States: Trends by Educational Attainment from 2001 to 2020. *Am J Prev Med*. 2024;67(3):319–27.
35. Karkhah MR, Arasteh M, Takasi P. Nutritional knowledge and related factors among patients with diabetes mellitus: A systematic review. *Journal of Nursing Reports in Clinical Practice*. 2024;3(Issue 1):69–77.
36. Goyal S, Rani J, Bhat MA, Vanita V. Genetics of diabetes. *World J Diabetes*. 2023;14(6):656.
37. Shojima N, Yamauchi T. Progress in genetics of type 2 diabetes and diabetic complications. *J Diabetes Investig*. 2023 Apr;14(4):503–15.
38. Klein S, Gastaldelli A, Yki-Järvinen H, Scherer PE. Why does obesity cause diabetes? *Cell Metab*. 2022 Jan;34(1):11–20.
39. Yu H jie, Ho M, Liu X, Yang J, Chau PH, Fong DYT. Association of weight status and the risks of diabetes in adults: a systematic review and meta-analysis of prospective cohort studies. *Int J Obes*. 2022;46(6):1101–13.
40. Yashi K, Daley SF. Obesity and type 2 diabetes. In: *StatPearls* [Internet]. StatPearls Publishing; 2023.
41. Liao YS, Tsai WC, Chiu LT, Kung PT. Educational attainment affects the diagnostic time in type 2 diabetes mellitus and the mortality risk of those enrolled in the diabetes pay-for-performance program. *Health Policy (New York)*. 2023;138:104917.
42. Choi JY, Choi D, Mehta NK, Ali MK, Patel SA. Diabetes Disparities in the United States: Trends by Educational Attainment from 2001 to 2020. *Am J Prev Med*. 2024;67(3):319–27.