Indonesian Journal of Global Health Research
Volume 7 Number 3, June 2025
e-ISSN 2715-1972; p-ISSN 2714-9749
http://jurnal.globalhealthsciencegroup.com/index.php/IJGHR

ASSOCIATIONS OF DIETARY INTAKE AND SOCIODEMOGRAPHIC FACTORS WITH THE INCIDENCE OF T2DM AMONG OBESE ADULTS

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ABSTRACT
Type 2 diabetes mellitus (T2DM) is a major public health concern, particularly among obese individuals. Dietary intake, including energy, protein, and fiber consumption plays a key role in metabolic health, with sociodemographic factors influencing its mechanisms. Objective: This study aimed to analyze the associations of these dietary factors and T2DM incidence in obese adults in Surakarta city. This cross-sectional study included 100 obese adults from Surakarta. T2DM status was determined based on their medical records. Dietary intake data were collected using Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ). Sociodemographic data were collected by interview. Multiple binary logistic regression was performed to analyze the association between dietary intake and T2DM with $p<0.05$. The most participants were female (75.0%) and Javanese (82.0%). Daily fiber intake was significantly associated with a lower risk of T2DM (OR=0.04, 95%CI=0.01–0.14, $p<0.001$), while ethnicity, educational history, occupation, and monthly personal expenses were identified as significant risk factors ($p<0.05$). Further analysis, only daily fiber intake (aOR=0.06, 95%CI=0.01–0.29, $p<0.001$) and occupation (aOR=16.81, 95%CI=3.98–71.08, $p<0.001$) remained significantly associated with T2DM. Adequate daily fiber intake was the strongest protective factor, while individuals engaged in work were the strongest predictor of T2DM among obese adults in Surakarta city.

Keywords: diabetes mellitus; dietary intake; obesity; sociodemographic

How to cite (in APA style)
Widiasih, G., Indarto, D., & Susilawati, T. N. (2025). Associations of Dietary Intake and Sociodemographic Factors with the Incidence of T2DM among Obese Adults. Indonesian Journal of Global Health Research, 7(3), 413-422. https://doi.org/10.37287/ijghr.v7i3.6136.

INTRODUCTION

Overweight and obesity are conditions of chronic excessive fat cell deposits, which represent a global health issue associated with increased rates of various non-communicable diseases (WHO, 2021; 2024). Currently, the global prevalence of obesity among adults has risen steadily since 1990. According to the World Health Organization (WHO), there were 2.5 billion overweight adults globally in 2022, with 890 millions of them classified as obese (WHO, 2024). In 2023, the Indonesian Health Survey (Survei Kesehatan Indonesia/SKI) reported that the proportion of overweight and obese adults in Indonesia was 14.4% and 23.4%, respectively. Central Java shows a high proportion of overweight and obese adults at 13.5% and 22.5%, respectively, with more than 40% residing in urban areas (Badan Kebijakan Pembangunan Kesehatan RI, 2023). Surakarta, the third-largest city in Java, after Malang and Bandung, has a population of adults over 18 years old of 374,562 individuals. The city has a notably high prevalence of adult obesity, marked at 31.2% in 2022, with an average annual increase of 0.7% since 2018 (Badan Pusat Statistik Kota Surakarta, 2023a).

Dietary intake plays a crucial role in the development of T2DM among obese adults, with total daily energy, protein, and fiber intake serving as some of key dietary determinants of metabolic health(Kheriji et al., 2022). Excessive energy intake, particularly from energy-dense, nutrient-poor foods high in refined carbohydrates and saturated fats, promotes chronic hyperinsulinemia and increased adiposity through persistent activation of insulin signaling pathways. This leads to insulin receptor downregulation and subsequent insulin resistance (Janssen, 2024). Prolonged overnutrition also results in hypertrophy and hyperplasia of adipocytes, leading to adipose tissue dysfunction characterized by excessive secretion of pro-inflammatory cytokines, which subsequently will disrupt insulin signaling and glucose uptake in skeletal muscle and liver (Clemente-Suárez et al., 2023). Protein intake also influences T2DM risk, though its effects are complex. Adequate protein intake supports lean body mass, enhances satiety, and promotes energy expenditure, which can be beneficial in obesity management (Akhavan et al., 2020). However, excessive protein consumption, particularly from animal sources, has been linked to increased insulin resistance and impaired glucose regulation (Ancu et al., 2021). Additionally, high protein intake can increase gluconeogenesis in the liver, contributing to hyperglycemia and β-cell stress overtime (Fappi & Mittendorfer, 2020). Conversely, daily fiber intake has been widely recognized for its protective effects against T2DM by improving glycemic control, enhancing insulin sensitivity, and modulating gut microbiota composition (Reynolds et al., 2020). Moreover, fiber fermentation by gut microbiota produces short-chain fatty acids (SCFAs), which enhance insulin sensitivity by activating free fatty acid receptors and improving gut barrier integrity. SCFAs also modulate systemic inflammation and reduce the secretion of pro-inflammatory cytokines that contribute to insulin resistance(He et al., 2020).

In addition to dietary factors, sociodemographic determinants such as age, sex, ethnicity, education, occupation, and socioeconomic status also influence the development of type 2 diabetes mellitus by shaping dietary patterns, healthcare access, and metabolic outcomes (Kendrick et al., 2023). Aging is a well-known risk factor, as older individuals experience a natural decline in insulin sensitivity and β-cell function, exacerbated by prolonged exposure to metabolic stress (Zhu et al., 2021). Sex-related differences in fat distribution and hormonal regulation also contribute to variations in T2DM risk, with men typically accumulating more visceral fat and women experiencing hormonal shifts, particularly during menopause, that may predispose them to insulin resistance (Estoppey et al., 2023). Similarly, cultural dietary patterns influence food sources and overall nutrient intake, further modulating T2DM risk across different populations, such as South Asians, Hispanics, and African Americans, exhibiting higher T2DM susceptibility (Kendrick et al., 2023). Sedentary jobs with minimal physical activity contribute to weight gain and metabolic dysfunction (Park et al., 2022), while lower educational history is associated with reduced health literacy, leading to poor dietary habits and limited awareness of preventive measures (Azizi Fard et al., 2021). Monthly personal expense disparities also restrict access to healthy foods, medical check-ups, and diabetes management resources, exacerbating disease progression (Patel, 2020). Understanding the complex interactions between dietary intake, sociodemographic factors, and T2DM incidences is essential for developing targeted dietary and lifestyle interventions to mitigate T2DM risk in obese adults. This study aimed to analyze the associations of daily energy, protein, fiber intake, and sociodemographic factors with T2DM incidence in obese adults in Surakarta city.

METHOD

This analytic observational cross-sectional study took place in Surakarta, Indonesia from June 2024 until January 2025. The inclusion criteria were adults aged≥18-year-old with body mass index (BMI)≥23.0 kg/m². Subjects that were pregnant, had an underlying condition that could

cause secondary obesity, and had other severe comorbidities such as Alzheimer, stroke, coronary heart disease and/or any heart disease, kidney disease, liver disease, and cachexia were excluded from the study. The minimum sample size was 91, as calculated using OpenEpi version 3 www.openepi.com (Dean et al., 2013).

A total of 100 participants were included in this study. The participants were recruited using social media advertisement or the outpatients from 3 primary healthcare facilities in Surakarta. T2DM status was determined based on their medical records. Daily energy, protein, and fiber intake were collected using a validated (r=0.78) and reliable (α=0.54) Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ). Dietary intake data were then analyzed using the NutriSurvey program (www.nutrisurvey.de) (Erhardt, 2010). Information about sociodemographic characteristics were collected by interview. The research protocol was approved by the Research Ethics Committee of Faculty of Medicine of Universitas Sebelas Maret (No. 121/UN27.06.11/KEP/EC/2024).

Numerical data were presented as mean and standard deviation (SD), while the categorical data were presented as proportions (%). Nominal or ordinal data with two or more categories were converted into two dummy variables. Bivariate analyses were performed using binary logistic regression. Independent and confounding variables with a $p<0.25$ in the bivariate analysis were further analyzed using multivariate analysis through multiple binary logistic regression. The analysis was conducted using IBM SPSS 29.0 for Mac with a significance level of $p<0.05$ and a 95% confident interval (CI).

RESULT

The study included a total of 100 overweight and obese adult participants (Table 1), the majority of whom were female (75.0%). Most participants identified as Javanese (82.0%), with smaller proportions representing other ethnic groups. The mean age of the participants was approximately 40.8 years. Educational history among participants ranged from no formal education (3.0%) to university-level studies (35.0%), reflecting diverse socioeconomic backgrounds. Similarly, employment status varied, with some participants actively engaged in the workforce while others were students (39.0%) or unemployed (37.0%). Daily dietary intake showed considerable variation. Additionally, most participants were obese (86.0%) and diagnosed with T2DM (60.0%).

The statistical analysis identified several dietary and sociodemographic factors significantly associated with the incidence of T2DM among obese adults in Surakarta (Table 2). Daily fiber intake showed a stronger protective effect against T2DM (OR=0.04, 95%CI=0.01–0.14, $p<0.001$) compared to other variables. Conversely, occupation (OR=27.0, 95%CI=8.93–81.61, $p<0.001$) was a stronger risk factor for T2DM compared to ethnicity (OR=4.49, 95%CI=1.21–16.59, p=0.025), educational history (OR=3.27, 95%CI=1.30–8.27, p=0.012), and monthly personal expenses (OR=2.99, 95%CI=1.30–6.87, p=0.010). In contrast, daily energy intake (OR=0.50, 95%CI=0.15–1.68, p=0.260), daily protein intake (OR=1.70, 95%CI=0.74–3.92, p=0.213), age (OR=0.00, 95%CI=0.00–0.00, p=0.997), and sex (OR=0.50, 95%CI=0.19–1.33, p=0.162) were not significantly associated with T2DM incidence. Given its theoretical relevance to T2DM, daily energy intake were then included in the multivariate analysis (Table 3).

Adequate daily fiber intake and occupation were the strongest associated factors with T2DM in obese adults among all variables included in the multivariate analysis, after adjusting for age. Adequate daily fiber intake showed the strongest inverse association with T2DM (aOR=0.06, 95% CI=0.01–0.29, $p<0.001$), with individuals who had adequate daily fiber

intake being 0.06 times less likely to develop T2DM compared to those with inadequate daily fiber intake. Meanwhile, occupation was positively associated with T2DM (aOR=16.81, 95%CI=3.98–71.08, p<0.001), with individuals enganged in work having 16.81 times higher odds of developing T2DM compared to those who were not working. Compared to the bivariate analysis, the aOR for adequate daily fiber intake increased from 0.04 (95%CI=0.01–0.14) to 0.06 (95%CI=0.01–0.29), meanwhile the aOR for individuals engaged in work decreased from 27.0 (95%CI=8.93–81.61) to 16.81 (95%CI=3.98–71.08) in the multivariate analysis. However, both remained statistically significant. In contrast, the aOR for excessive daily energy intake increased from 0.50 (0.15-1.68) to 0.71 (0.06-8.18), excessive daily protein intake increased from 1.70 (95%CI=0.74–3.92) to 2.05 (95%CI=0.51–8.22), and male sex increase from (0.19-1.33) to 0.82 (0.18-3.83). However, none were statistically significant. Furthermore, higher educational level, Javanese ethnicity, and higher monthly personal expenses, which were significant in the bivariate analysis, became non-significant.

Table 1.
Characteristics of Study Participants (n=100)

Characteristics	f (%)	Mean ($\bar{x}$±SD)
Age (year)		40.8±18.8
<38-year-old	50 (50.0)	
≥38-year-old	50 (50.0)	
Sex		
Male	25 (25.0)	
Female	75 (75.0)	
Ethnicity		
Javanese	82 (82.0)	
Chinese-Indonesian	3 (3.0)	
Malay	3 (3.0)	
Batak	3 (3.0)	
Sumbanese	3 (3.0)	
Minangkabau	2 (2.0)	
Makassarese	2 (2.0)	
Arab-Indonesian	1 (1.0)	
Acehnese	1 (1.0)	
Educational history		
No formal education	3 (3.0)	
Primary school	11 (11.0)	
Middle school	10 (10.0)	
High school	41 (41.0)	
University	35 (35.0)	
Occupation		
Unemployed	37 (37.0)	
Student	39 (39.0)	
Private sector worker	12 (12.0)	
Civil servant	3 (3.0)	
Self-employed	9 (9.0)	
Monthly personal expenses*		
Vulnerable	15 (15.0)	
Emerging middle class	34 (34.0)	
Middle class	26 (26.0)	
High-income	25 (25.0)	
BMI (kg/m^2)**		28.7±4.1
Overweight	14 (14.0)	
Obese I	53 (53.0)	
Obese II	33 (33.0)	
T2DM		
Yes	40 (40.0)	
No	60 (60.0)	
Daily energy intake (kcal/day)***		1998.6±946.7
Escessive (≥2600.0)	15 (15.0)	

Characteristics	f (%)	Mean (x̄±SD)
Not excessive (<2600.0)	85 (85.0)	
Daily protein intake (g/day)***		95.5±98.8
Escessive (≥70.0)	60 (60.0)	
Not excessive (<70.0)	40 (40.0)	
Daily fiber intake (g/day)***		28.3±8.4
Adequate (≥25.0)	56 (56.0)	
Inadequate (<25.0)	44 (44.0)	

*Monthly personal expenses were classified based on World Bank criteria from SUSENAS 2021 (Badan Pusat Statistik Kota Surakarta, 2021)

**BMI were classified based on WHO Asia-Pacific criteria (WHO, 2000)

***Dietary intake cutoffs were based on Recommended Dietary Allowance (RDA) from Peraturan Menteri Kesehatan No. 28 of 2019 (Kementrian Kesehatan Republik Indonesia, 2019).

Table 2.
Bivariate Analysis between Dietary Intake and Sociodemographic Factors on the Incidence of T2DM among Obese Adults

Variables	B	OR (95%CI)	p
Daily energy intake	0.703	0.50 (0.15-1.68)	0.260
Daily protein intake	0.530	1.70 (0.74-3.92)	0.213
Daily fiber intake	-3.281	0.04 (0.01-0.14)	<0.001*
Age	-22.589	0.0 (0.00-0.00)	0.997
Sex	-0.703	0.50 (0.19-1.33)	0.162
Ethnicity	1.501	4.49 (1.21-16.59)	0.025*
Educational history	1.186	3.27 (1.30-8.27)	0.012*
Occupation	3.296	27.0 (8.93-81.61)	<0.001*
Monthly personal expenses	1.094	2.99 (1.30-6.87)	0.010*

*Statictically significant (p<0.05)

Table 3.
Multiple Binary Logistic Regression Analysis between Dietary Intake and Sociodemographic Factors on the Incidence of T2DM among Obese Adults

Variables	B	aOR (95%CI)	p
Excessive daily energy intake	0.339	0.71 (0.06-8.18)	0.785
Excessive daily protein intake	0.719	2.05 (0.51-8.22)	0.310
Adequate daily fiber intake	-2.770	0.06 (0.01-0.29)	<0.001*
Male sex	-0.198	0.82 (0.18-3.83)	0.801
Javanese ethnicity	0.765	2.15 (0.24-19.17)	0.493
Higher education level	0.928	2.53 (0.52-12.22)	0.248
Work	2.822	16.81 (3.98-71.08)	<0.001*
Higher monthly personal expenses	0.869	2.38 (0.63-8.98)	0.199

*Statictically significant (p<0.05)

DISCUSSION

The majority of respondents in this study were female and of Javanese ethnicity. This is consistent with government data, which shows that the population of Surakarta aged over 18 years is dominated by females, who outnumber males by 5.48%, and that almost 95% are of Javanese ethnicity, although a small proportion of other ethnic groups also reside in the city (Badan Pusat Statistik Kota Surakarta, 2023a; 2023b). The present study identified adequate daily fiber intake as a significant protective factor and individuals engaged in work as a major risk factor for T2DM among obese adults in Surakarta. These associations remained

significant even after adjusting for age. The strong inverse relationship between adequate daily fiber intake and T2DM risk aligns with previous research demonstrating that fiber improves insulin sensitivity, regulates blood glucose levels, and promotes gut microbiota diversity (Reynolds et al., 2020). However, the source of fiber, such as fruits, vegetables, or whole grains, should be considered, as different types of fiber have varying metabolic benefits. For example, a diverse intake of plant-based fiber is more effective in preventing metabolic and cardiovascular diseases (Bulsiewicz, 2023). Certain fiber sources may have a more pronounced impact on glycemic control, while others may contribute additional macronutrients that could modify overall dietary risk factors (Hoffmann Sarda & Giuntini, 2023).

Therefore, appropriate selection of fiber sources could potentially enhance the prevention of T2DM among obese adults. The adjusted odds ratio (aOR=0.06, 95%CI=0.01–0.29) suggests that individuals with adequate fiber intake had a substantially 0.06 times lower risk of developing T2DM. This findings highlight the urgent need for dietary interventions aimed at increasing fiber consumption among obese individuals to mitigate the risk of T2DM, as shown in previous study (Waddell & Orfila, 2023). Occupation was also found to be a strongest predictor of T2DM incidence, with individuals enganged in work exhibiting significantly 16.81 times higher odds of developing the disease (aOR=16.81, 95%CI=3.98–71.08). This finding suggests that occupational factors may contribute to increased T2DM risk. Work-related stress, sedentary behaviour, and poorer dietary habits had been shown to increase the risk of T2DM among night-shift workers in Finland (Hemiö et al., 2020) Studies in South Korea have reported that working more than 52 hours per week and working in shift are associated with metabolic disorders, including insulin resistance (Seo et al., 2022). Additionally, the workplace environment may influence dietary habits, with employed individuals potentially consuming more processed foods and having irregular meal patterns (McCurley et al., 2022). As the participants were mostly students, these findings were understandable. Students experienced high stress levels due to academic demands, leading to frequent meal skipping, an unbalanced diet, and a lack of physical activity (Choi, 2020).

Interestingly, daily energy intake was not significantly associated with T2DM incidence in this study. One possible explanation is that total energy intake alone may not be a sufficient predictor of T2DM risk in obese individuals, as metabolic responses to excess energy intake can vary based on diet composition, physical activity levels, and genetic predisposition (Petroni et al., 2021). Additionally, differences in macronutrient distribution, such as the proportion of carbohydrates, fats, and proteins in the diet, may influence glucose metabolism independently of total caloric intake (Park et al., 2022). Furthermore, daily protein intake was not significantly associated with T2DM, despite an increase in its adjusted odds ratio (aOR=2.05, 95%CI=0.51–8.22) compared to the bivariate analysis. The role of protein in T2DM development remains controversial, as some studies suggest that high protein intake, particularly from animal sources, may impair insulin sensitivity (Mensink, 2024), while others indicate a protective effect through muscle mass preservation and satiety regulation (Hansen et al., 2021).

As for sociodemographic factors**,** ethnicity, educational history, and monthly personal expenses were found to be significantly associated with the incidence of T2DM among obese adults in bivariate analysis. However, these variables lost their statistical significance in the multivariate analysis, suggesting that their effects may be influenced by other factors. Ethnicity, for instance, initially showed a significant association with T2DM (p=0.025), but when adjusted for age, its influence diminished (p=0.493). This finding aligns with previous studies indicating that genetic predisposition alone may not be a primary determinant of

T2DM risk (Sirdah & Reading, 2020), and environmental factors such as dietary habits and lifestyle choices play a more dominant role (Cao et al., 2024). Similarly, higher education levels were initially linked to T2DM risk (OR=3.27, 95%CI=1.30–8.27, p=0.012), possibly due to better awareness of health-related behaviors. However, when controlled for occupation and income-related factors, education no longer remained a significant predictor (p=0.248). This result may indicate that socioeconomic status, rather than education itself, has a more direct impact on T2DM incidence (Grjibovski et al., 2020). Furthermore, while higher monthly personal expenses were associated with an increased risk of T2DM in the bivariate analysis (p=0.010), this relationship was no longer significant in the multivariate model (p=0.199). This suggests that personal expenses alone do not directly influence T2DM risk but rather interact with other determinants such as dietary intake and occupational status (Hernández-Teixidó et al., 2023). These findings highlight the complexity of T2DM risk factors and emphasize the need to consider multiple interacting variables when assessing the disease's determinants. This study provides a comprehensive analysis of the associations of dietary intake and sociodemographic factors with the incidence of T2DM among obese adults in Surakarta. Further research with a more representative sample, varied studiy settings, and prospective cohort designs is needed to explore the long-term impact of dietary and occupational interventions and to develop tailored strategies for high-risk populations.

CONCLUSION

Adequate daily fiber intake was the strongest protective factor, while individuals engaged in work were the strongest predictor of T2DM among obese adults in Surakarta city, compared to those with inadequate daily fiber intake and those who were not working. These findings underscore the critical role of adequate fiber intake in T2DM prevention and the need to address occupational factors that contribute to the disease. Exploring specific sources and types of dietary fiber that contribute most effectively to reduce diabetes risk in the population with targeted public health interventions, including school or university wellness programs and community-based dietary education, may help mitigate the risk of T2DM among obese individuals in Surakarta city.

ACKNOWLEDGEMENTS

Authors thank all the participants and the study sites (Biomedical Laboratorium of Medical Faculty of Universitas Sebelas Maret, Persatuan Diabetes Indonesia (Persadia) Surakarta, Majelis Tafsir Al-Qur'an Primary Healthcare, and Nurifa Primary Healthcare. We further extend our gratitude to everyone who contributed in data collection. This study is part of the project Metabolic Profiles of Indonesian Adults with Obesity Based on the Genetic Variations of DPP4, GLP1 Receptor, CD36, and PTP1B: A Pilot Study for 2024–2025, funded under the International Collaborative Research scheme (194.2/UN27.22/PT.01.03/2024).

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