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Original Article

# Obesity indices and ultra-processed food intake in relation to diabetes mellitus: a cross-sectional study

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## Abstract

Diabetes mellitus remains a major global health problem. Lifestyle changes associated with modernization increase obesity and ultra-processed food consumption, both considered risk factors for diabetes. Obesity can be assessed using several anthropometric indices, such as BMI, WC, WHR, and WHrT. This study aimed to determine the relationship between the obesity index and ultra-processed food consumption with the incidence of diabetes mellitus. This quantitative cross-sectional study was conducted in Semarang from January to May 2025 among 75 adults aged 26–45 years selected by purposive sampling. Fasting blood glucose was measured using the glucose oxidase enzymatic method. The obesity indices were assessed through anthropometric measurements, while ultra-processed food intake was obtained using a modified semi-quantitative food frequency questionnaire. Data were analyzed using univariate and bivariate tests, including the independent t-test, the Mann-Whitney U test, and the Pearson test.: Diabetes mellitus was identified in 30.7% of respondents, and 46.7% had a high WHR. WHR showed the highest predictive ability for diabetes mellitus (AUC=0.76). Ultra-processed food intake contributed 30.29% of total daily energy intake, with 44% of respondents in quintile 4. WHR was significantly associated with diabetes mellitus (r=0.563; p=0.01), whereas ultra-processed food intake was not (r=0.333; p=0.077). WHR is the best indicator of diabetes mellitus, whereas consumption of ultra-processed foods showed no significant association in this study.

**Keywords:** diabetes mellitus, obesity, ultra-processed food, waist-to-hip ratio

## Introduction

Indonesia is experiencing rapid technological development, environmental changes, and lifestyle modernization, resulting in shifts in disease patterns, now dominated by non-communicable diseases. One of the priority health issues in Indonesia is diabetes mellitus (DM). Based on the 2018 Basic Health Research report, the prevalence of DM was 10.9% [1]. The prevalence of DM has increased, as shown by data from the Indonesian Health Survey in 2023: 11.7% of the population aged >15 years had DM based on blood sugar testing. Type 2 diabetes (T2DM) is more commonly found in the productive age group (52.1%) and the elderly (48.9%) compared to type 1 diabetes in the productive age group (15.5%) and the elderly (17.8%) [2]. The International Diabetes Federation (IDF) ranked Indonesia 5$^{th}$ in the world in 2024, with 20.4 million people with DM, or 11.3%. The number of people with diabetes in Indonesia is estimated to increase to 254 million people in 2050. This condition has the potential to reduce the productivity and quality of life of the Indonesian population [3].

The increase in DM prevalence also occurred in Central Java by 2.3% in 2023 compared to 2.1% in 2018. The Central Java Provincial Health Profile reported that diabetes mellitus was 1 of the 3 non-communicable diseases with a high prevalence in Central Java, namely 8.7% in 2024. The number of T2DM cases in Semarang City in 2024 was 43,557, down from 48,119

in 2023. However, the number of T2DM cases remains high and warrants serious consideration. The highest number of T2DM cases in Semarang City in 2024 was in the Kedungmundu area, with 3,192 cases (1,150 in men and 2,042 in women) [4].

The increasing incidence of T2DM is closely related to obesity. The prevalence of obesity among Indonesians aged >15 years in 2023 was 23.4%, with the highest prevalence among women (31.2%) compared with men (15.7%) [2]. The risk of T2D is 4.6 times higher in women and 3.5 times higher in men with a body mass index (BMI) of more than 29.9 kg/m$^2$ [5]. Excessive body fat accumulation contributes to a decreased response of pancreatic beta cells to blood glucose and a decrease in the number and sensitivity of insulin, which impacts insulin resistance. In obese individuals, leptin levels, an adipokine that regulates energy homeostasis, increase, inhibiting the phosphorylation of insulin receptor substrate-1 (IRS-1) and contributing to elevated blood glucose levels [6]. Obesity can be identified using anthropometric measurements, such as body mass index. However, BMI has limitations because it does not account for body fat distribution, particularly abdominal fat. Alternative measurements besides body mass index include waist-to-hip and waist-to-height ratios as obesity indices that can be used to screen for central obesity, which better reflect abdominal fat accumulation than BMI [7, 8]. Results from meta-analyses conducted across several Asian countries indicate that the waist-to-height ratio can be used as a simple, non-invasive tool to identify central obesity and predict the risk of diabetes and cardiovascular disease [9, 10]. Central obesity is a more accurate predictor of type 2 diabetes risk than body mass index. Each one-unit increase in BMI is associated with a 33% increase in the risk of type 2 diabetes in men and a 67% increase in women. Meanwhile, each one-unit increase in the waist-to-hip ratio is associated with a greater increase in the risk of type 2 diabetes, namely 87% and 84% in men and women [11].

Other risk factors for type 2 diabetes include age, gender, genetics, high dietary intake of processed foods, such as ultra-processed foods, and a sedentary lifestyle. The rapid development of food technology and marketing has triggered a shift in global food consumption patterns, marked by increased consumption of ultra-processed foods. The contribution of ultra-processed foods to daily intake continues to increase, with more than 50% of adults' daily energy intake from ultra-processed foods [12]. In Indonesia, 21.1% of total daily energy intake in adults comes from UPF consumption [13].

Ultra-processed foods, such as sweetened drinks, instant foods, and frozen foods, generally have a high energy density due to their excessive sugar, salt, and fat content and low fiber content [14]. In Indonesia, the habit of consuming risky foods, especially ultra-processed foods, is still relatively high. The proportions of sweet food consumption, sweet drinks, salty foods, fatty foods, processed foods with preservatives, soft drinks, energy drinks, and instant foods are 33.7%, 47.5%, 30.4%, 37.4%, 7.8%, 2.5%, 1.6%, and 5.9%, respectively [2]. Excessive intake of ultra-processed foods will increase total energy intake and low diet quality, contributing to an increased risk of obesity and other chronic diseases such as diabetes. A 10% increase in daily consumption of ultra-processed foods will increase the risk of diabetes by 15% [15]. High intake of ultra-processed foods disrupts the insulin signaling pathway, thereby increasing the risk of type 2 diabetes. Food additives such as sweeteners and emulsifiers, which are often found in ultra-processed foods, can increase insulin resistance and inflammation by disrupting the gut microbiota-host relationship [16, 17]. This study aims to determine the relationship between the obesity index and consumption of ultra-processed foods with the risk of increased blood sugar levels in Semarang City.

## Material and methods

### Study design

This study is an observational, cross-sectional study conducted in Semarang City from May – July 2024. The population in this study is adults residing in Kedungmundu, Semarang City. The total sample size for this study was 75, obtained through purposive sampling, with participants selected to meet the research criteria. The inclusion criteria for this study were: 1) residents of the Kedungmundu area, aged 26–45 years; 2) not taking medications related to diabetes mellitus; 3) not on a special diet; 4) not having a habit of consuming alcohol; 5) not having comorbidities (liver or kidney disorders); and 6) willing to be respondents, conscious, able to communicate well, and signed an informed consent. The sample exclusion criteria for this study were: 1) moving domicile during data collection; 2) being ill at the time of data collection.

#### Laboratory assessment

Blood glucose levels were examined by taking a 5 ml plasma sample in the morning after the respondents

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had fasted overnight. Blood samples were collected once and analyzed by laboratory personnel at the Kedungmundu Community Health Center using the glucose oxidase enzymatic method. The blood glucose values obtained were then used, based on the Guidelines for the Management and Prevention of Type 2 Diabetes Mellitus in Indonesia, to determine the incidence of diabetes mellitus in this study: fasting blood glucose levels ≥126 mg/dL were considered T2DM. At the same time, a level of <126 mg/dL was considered not to indicate T2DM [18].

### Anthropometric data collection

The distribution of body fat is measured by trained nutritionists using anthropometry, such as Body Mass Index (BMI), waist circumference (WC), hip circumference (HC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR). Weight was measured without shoes and in light clothing to the nearest 0.1 kg on a calibrated beam scale. Height was measured without shoes to the nearest 0.2 cm using a portable stadiometer. BMI is an anthropometric index widely used to determine the prevalence of obesity, based on the Asia-Pacific cut-off of 18.5–22.9 kg/m$^2$, and is considered normal for nutritional status. BMI was calculated as weight (kg)/height (m)2. A BMI of less than 18.5 kg/m$^2$ is considered underweight, greater than or equal to 23.0 kg/m$^2$ or less than 24.9 kg/m$^2$ is considered overweight, and a BMI greater than 25 kg/m$^2$ is considered obese [19].

Waist circumference was measured during expiration at the midpoint between the lowest rib and the superior iliac prominence using a horizontal measuring tape with a minimum length of 150 cm and an accuracy of 0.1 cm. WC was classified as normal if it was <80 cm in women and <90 cm in men, and as central obesity if it was >80 cm in women and >90 cm in men [9]. Respondents' HC was measured at the widest part of the hips or buttocks, with the measuring tape kept parallel to the floor and not pressing on fat tissue. Waist and hip circumference measurements were taken twice, and the average was calculated and reported in cm. The results of waist and hip circumference measurements were used to calculate the waist-to-hip ratio (WHR), which was obtained by dividing the waist circumference (cm) by the hip circumference (cm). The waist-to-hip ratio was classified as normal if it was <0.9 in men and <0.8 in women. The waist-to-hip circumference ratio is considered high if it is ≥0.9 in men and ≥0.8 in women [9].

Waist-to-height ratio (WHtR) was calculated by dividing WC (cm) by height (cm). The general cutoff point for WHtR>0.5 is considered obese, and WHtR≤0.5 is considered normal; no difference is made between males and females [9].

### Intake data collection

Food intake data, including daily intake and ultra-processed food intake, were collected via semi-quantitative food frequency questionnaire (SQ-FFQ) interviews. The data obtained describes respondents' food intake over the last month. The SQ-FFQ instrument used is a questionnaire developed by the research team that includes additional types of ultra-processed foods and beverages, totaling 123 items. Ultra-processed food consumption data were then classified based on the energy contribution of ultra-processed foods to total energy intake, including quintile 1 (<7.25% total energy/day), quintile 2 (7.26–14.88% total energy/day), quintile 3 (14.89–24.10% total energy/day), quintile 4 (24.11–37.54% total energy/day), and quintile 5 (≥37.55% total energy/day) [13]. Total energy intake was calculated from respondents' one-month food and beverage intake using the SQ-FFQ instrument.

## Statistical analysis

The data in this study were analyzed using univariate and bivariate tests. Univariate analysis was conducted to provide descriptive information on respondent characteristics (sex, age, occupation, educational level, household income, marital status, number of family members, physical activity, and smoking habits) and the study variables (T2DM, obesity index, and UPF intake). Data were analyzed using Microsoft Excel 2019 and IBM SPSS Statistics version 26. Bivariate analysis was used to assess the relationships between the obesity index, ultra-processed food consumption, and T2DM. Ratio-scale data were tested for normality using the Kolmogorov–Smirnov test. Difference tests on normally distributed data were analyzed using the Independent t-test, whereas non-normally distributed data were analyzed using the Mann–Whitney U test. To test the relationship between variables, the Pearson and Spearman tests were used. Statistical significance was determined at $p<0.05$.

Receiver operating characteristic (ROC) curve analysis was performed to predict the sensitivity and specificity of diabetes mellitus incidence measurement in this study, using the Youden index (sensitivity + specificity - 1) to calculate the optimal threshold value of anthropometric indices [20]. The area under the ROC curve (AUC) with 95% CI was estimated for four

anthropometric indices (BMI, WC, WHR, WHtR). The ability of different indices to identify DM incidence based on the AUC prediction performance was classified as excellent (AUC≥0.9), fair (0.8≤AUC<0.9), moderate (0.7≤AUC<0.8), poor (0.6≤AUC<0.7), or failure (0.5≤AUC<0.6) [21].

## Results

The incidence of type 2 diabetes mellitus (DM) in this study was 30.7%. Table 1 shows the distribution of respondent characteristics in the DM and non-DM groups; no statistical differences were observed for any characteristic. The gender distribution showed a higher proportion of women (84%) in both groups, but the difference was not significant. Similarly, education level, employment type, and income level did not show significant differences between the diabetic and non-diabetic groups.

The average ages of respondents in the diabetic and non-diabetic groups were comparable, as were anthropometric parameters, including weight, height, body mass index (BMI), waist circumference (WC), hip circumference (HC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR). Although the prevalence of obesity tended to be higher in the non-diabetic group than in the diabetic group, this difference did not reach statistical significance.

Energy, carbohydrate, protein, and fat intake from both total and ultra-processed foods did not differ significantly between the two groups. In this study, ultra-processed food intake contributed 30.29% of the total energy intake, and 44% of respondents were in quintile 4 (24.11–37.54% of total energy/day). Furthermore, the proportions of carbohydrate and fat intake from ultra-processed foods (UPF), including their energy contributions and percentage distributions, did not differ significantly. This indicates that UPF consumption patterns were relatively similar in respondents with and without diabetes.

Lifestyle variables such as physical activity level and smoking status also did not show significant differences between the two groups. The majority of respondents in both groups had light to moderate levels of physical activity, and most were non-smokers.

Obesity indices exhibit varying predictive power for diabetes mellitus (DM), as shown in Table 2. At an AUC of 0.68, body mass index (BMI) with a cutoff of 26.4 kg/m$^2$ demonstrated a sensitivity of 47.8% and a specificity of 40.4%, indicating modest discriminatory capacity. Waist circumference at a cutoff point of 84.6 cm showed a sensitivity of 56.5%, specificity of 40.5%, and an AUC value of 0.67. The waist-to-hip ratio (WHR) performed best, with a cutoff of 0.86, sensitivity of 56.5%, specificity of 59.6%, and the highest AUC of 0.76, indicating good discriminatory capacity. On the other hand, with an AUC of 0.64, the waist-to-height ratio (WHtR) at a cutoff of 0.47 showed very high sensitivity (95.7%) but low specificity (13.5%). Compared with other anthropometric markers, WHR offers a better balance of sensitivity and specificity, making it the most ideal for predicting DM in this study population.

Based on the results of the correlation analysis presented in Table 3, only WHR showed a significant relationship with the incidence of Diabetes Mellitus (r=0.563; p=0.01), with a moderate-to-strong positive correlation. This finding indicates that increased abdominal fat distribution can increase the risk of DM. In contrast, other anthropometric variables, including BMI, WC, and WHtR, showed positive correlations but did not reach statistical significance (p>0.05). Similarly, the variables of total energy intake, total fat, and the contribution of energy and fat from UPF, including the percentage of total energy from UPF, did not show a significant relationship with the incidence of DM. Overall, these results confirm that WHR is the most relevant indicator of DM risk compared with general anthropometric measurements and energy intake factors in the studied population, while also reinforcing the importance of visceral fat distribution as a significant determinant of metabolic disorders.

## Discussion

Obesity is closely linked to an increased risk of type 2 diabetes mellitus (DM) or other metabolic diseases. Anthropometric measurements can be used to determine the incidence of obesity. Anthropometry is a non-invasive method used to determine nutritional status and the risk of malnutrition [8, 22]. Anthropometric measurements can be used to determine the obesity index. The obesity index associated with DM incidence in this study was the waist-to-hip ratio alone.

Meanwhile, BMI, WC, and WHtR did not show a significant relationship, although they did show a positive correlation. The most commonly used obesity index is BMI, but it has the disadvantage of not distinguishing between muscle mass and visceral fat [22, 23]. This is supported by the results, which found that BMI was the lowest anthropometric indicator (AUC: 0.54)


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Table 1: Summary statistics and a comparison of characteristics between the diabetic and non-diabetic groups.

| Characteristics | Diabetic (n=23, 30.7%) | Non-diabetic (n=52, 69.3%) | Total (n=75) | p-value |
|---|---|---|---|---|
| **Sex, n (%)** | | | | |
| Man | 6 (8.0%) | 6 (8.0%) | 12 (16.0%) | 0.170 |
| Woman | 17 (22.7%) | 46 (61.3%) | 63 (84.0%) | |
| **Level Education, n (%)** | | | | |
| Low Education | 4 (5.3%) | 6 (11.5%) | 10 (13.3%) | 0.484 |
| High Education | 19 (25.3%) | 46 (61.3%) | 65 (86.7%) | |
| **Occupation, n (%)** | | | | |
| Unemployed | 11 (14.7%) | 29 (38.7%) | 40 (53.3%) | 0.525 |
| Working | 12 (16.0%) | 23 (30.7%) | 35 (46.7%) | |
| **Family Income, n (%)** | | | | |
| Low income | 1 (1.3%) | 3 (4.0%) | 4 (5.3%) | |
| Middle income | 9 (12.0%) | 27 (36.0%) | 36 (48.0%) | 0.523 |
| High income | 13 (17.3%) | 22 (29.3%) | 35 (46.7%) | |
| **Age (years)** | 36.30±6.17 | 36.83±5.96 | 36.67±5.99 | 0.70 |
| **Weight (kg)** | 66.86±14.84 | 67.12±12.23 | 67.07±12.98 | 0.619 |
| **Height (cm)** | 158.52±7.78 | 157.51±8.17 | 157.82±8.02 | 0.925 |
| **BMI (kg/m$^2$)** | 26.47±4.83 | 27.06±4.36 | 26.88±4.49 | 0.605 |
| **BMI, n (%)** | | | | |
| Underweight | 1 (1.3%) | 0 (0.0%) | 1 (1.3%) | |
| Normal | 4 (5.3%) | 11 (14.7%) | 15 (20.0%) | 0.280 |
| Overweight | 5 (6.7%) | 6 (8.0%) | 11 (14.7%) | |
| Obese | 13 (17.3%) | 35 (46.7%) | 48 (64.0%) | |
| **WC (cm)** | 88.55±12.15 | 87.01±10.95 | 87.49±11.28 | 0.590 |
| **Cut off WC** | | | | |
| Normal | 5 (6.7%) | 9 (12.0%) | 14 (18.7%) | 0.750 |
| High | 18 (24.0%) | 43 (57.3%) | 61 (81.3%) | |
| **HC (cm)** | 101.45±9.32 | 103.29±9.82 | 102.72±9.65 | 0.452 |
| **WHR** | 0.87±0.06 | 0.84±0.07 | 0.85±0.07 | 0.075 |
| **Cut off WHR, n (%)** | | | | |
| Normal | 11 (14.7%) | 29 (38.7%) | 40 (53.3%) | 0.525 |
| High | 12 (16.0%) | 23 (30.7%) | 35 (46.7%) | |
| **WHtR** | 0.56±0.07 | 0.55±0.07 | 0.55±0.72 | 0.821 |
| **Cut off WHtR, n (%)** | | | | |
| Normal | 6 (8.0%) | 12 (16.0%) | 18 (24.0%) | 0.778 |
| High | 17 (22.7%) | 40 (53.3%) | 57 (76.0%) | |
| **Energy total (kkal)** | 1656.58±557.98 | 1613.96±699.19 | 1643.51±600.26 | 0.779 |
| **Carbohydrate total (gram)** | 224.87±74.27 | 206.50±87.45 | 219.24±78.41 | 0.228 |
| **Fat (gram)** | 56.38±27.88 | 55.19±21.88 | 55.56±23.69 | 0.842 |

Table 1: Continued.

| Characteristics | Diabetic (n=23, 30.7%) | Non-diabetic (n=52, 69.3%) | Total (n=75) | p-value |
|---|---|---|---|---|
| **Energy from UPF (kkal)** | 520.65±293.29 | 501.64±403.93 | 515.12±328.42 | 0.828 |
| **Carbohydrate form UPF (gram)** | 47.30±40.01 | 50.30±34.82 | 49.38±36.25 | 0.476 |
| **Fat form UPF (gram)** | 26.87±13.49 | 25.79±19.35 | 26.53±15.39 | 0.782 |
| **Dietary Variety, n (%)** | | | | |
| Varied | 8 (10.7%) | 26 (34.7%) | 24 (45.3%) | 0.222 |
| Less varied | 15 (20.0%) | 26 (34.7%) | 41 (54.7%) | |
| **Contribution of UPF to total energy (%)** | 30.46±10.69 | 29.89±15.48 | 30.29±12.25 | 0.874 |
| **UPF quartiles, n (%)** | | | | |
| Q1 | 1 (1.3%) | 0 (0.0%) | 1 (1.3%) | 0.172 |
| Q2 | 3 (4.0%) | 4 (5.3%) | 7 (9.3%) | |
| Q3 | 6 (8.0%) | 10 (13.3%) | 16 (21.3%) | |
| Q4 | 6 (8.0%) | 27 (36.0%) | 33 (44.0%) | |
| Q5 | 7 (9.3%) | 11 (14.7%) | 18 (24.0%) | |
| **Physical activity, n (%)** | | | | |
| Low physical activity | 5 (6.7%) | 4 (5.3%) | 9 (12.0%) | 0.253 |
| Moderated physical activity | 6 (8.0%) | 16 (21.3%) | 22 (29.3%) | |
| High physical activity | 12 (16.0%) | 32 (42.7%) | 44 (58.7%) | |
| **Smoking status, n (%)** | | | | |
| Non smoker | 21 (28.0%) | 49 (65.3%) | 70 (93.3%) | 0.639 |
| Smoker | 2 (2.7%) | 3 (4.0%) | 6 (6.7%) | |

Note: Results are shown as means±SD unless stated otherwise. The comparison of characteristics between DM and non DM (Independent T-test or Mann-Whitney test for numerical data, Chi-square test and Fisher's exact test for categorical data). BMI – body mass index; WC – waist circumference; HC – hip circumference; WHR – waist-to-hip ratio; WHtR – waist-to-height ratio; UPF – ultra-processed food.

for detecting incident type 2 DM. BMI cannot differentiate between visceral fat mass, lean mass, and subcutaneous fat, often failing to identify individuals with metabolic obesity, even when their total body weight is not very high [22]. The nutritional status of respondents in this study, as measured by BMI, did not differ between the diabetic and non-diabetic groups. This indicates that there is variation in fat distribution between individuals and populations, with most research respondents having an obese nutritional status.

Table 2: Comparison of Area Under Curve (AUC), Based Body Mass Index, Waist Circumference, Waist-To-Hip Ratio, and Waist-To-Height Ratio for type 2 diabetes mellitus.

| Predictor | Cut point | Sensitivity | Specificity | AUC |
|---|---|---|---|---|
| **BMI** | 26.4 | 47.8 | 40.4 | 0.54 |
| **WC** | 84.6 | 56.5 | 40.5 | 0.67 |
| **WHR** | 0.86 | 56.5 | 59.6 | 0.76 |
| **WHtR** | 0.47 | 95.7 | 13.5 | 0.68 |

Note: BMI – body mass index; WC – waist circumference; WHR – waist to hip ratio; WtHR – waist to height ratio.


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Table 3: Correlation analysis of obesity index and intake on the incidence of diabetes mellitus.

| Variable | Diabetes mellitus | |
|---|---|---|
| | r | p |
| **BMI** | 0.168 | 0.594 |
| **WC** | 0.321 | 0.089 |
| **WHR** | 0.563 | 0.01* |
| **WHtR** | 0.301 | 0.154 |
| **Energy total (kkal)** | 0.271 | 0.078 |
| **Fat (gram)** | 0.353 | 0.087 |
| **Energy from UPF (kkal)** | 0.249 | 0.362 |
| **Fat from UPF (kkal)** | 0.259 | 0.208 |
| **%UPF total energy** | 0.333 | 0.077 |

Note: Pearson test; * – Correlation is significant at the 0.05 level. BMI – body mass index; WC – waist circumference; WHR – waist to hip ratio; WtHR – waist to height ratio.

In this study, the waist-to-hip ratio was found to be a good anthropometric indicator with high sensitivity and specificity for predicting type 2 diabetes. The superiority of WHR as a predictor of diabetes risk can be biologically explained through its role in describing body fat distribution, particularly visceral fat. A high waist-to-hip ratio indicates increased visceral fat distribution. This is associated with a higher risk of type 2 diabetes mellitus (DM) than general obesity, as measured by total body mass [24, 25]. The results of this study (Table 3) indicate that higher WHR is associated with increased risk of type 2 diabetes. Excess visceral fat is often referred to as "central obesity" because it surrounds internal organs and enters the portal circulation, affecting glucose metabolism and insulin sensitivity in the liver, muscle, and subcutaneous adipose tissue. Increased visceral fat can trigger inflammation by decreasing adiponectin and increasing TNF-α and IL-6, thereby impairing insulin signaling and contributing to insulin resistance, increasing the risk of type 2 diabetes mellitus and other metabolic diseases [22–24]. An increase in visceral adiposity index (VAI), which reflects visceral fat distribution, is significantly associated with an increased risk of type 2 diabetes mellitus, with each unit increase in VAI associated with a relative increase in the risk of T2DM of more than 40% in several adult populations [24, 25].

Overall and ultra-processed food intake is a risk factor for type 2 diabetes mellitus. The high sugar, saturated fat, and trans-fat content, as well as additives in ultra-processed foods, can directly affect the body's metabolic response by affecting blood glucose levels and insulin sensitivity [26]. The high glycemic index of ultra-processed foods causes glucose spikes and insulin resistance, thereby increasing the risk of diabetes mellitus and other metabolic disorders. High UPF consumption increases the synthesis of pro-inflammatory cytokines such as C-reactive protein (CRP), interleukin-6 (IL-6), and TNF-α, and triggers the production of free radicals that stimulate oxidative stress in body tissues, including the pancreas and adipose tissue, thus contributing to insulin resistance and pancreatic β-cell dysfunction, which are the pathogenesis of T2DM [27, 28]. Several prospective cohort meta-analyses have reported that every 10% increase in the percentage of energy from ultra-processed foods is associated with an increased risk of T2DM [15].

The results of this study indicate that UPF intake contributed 30.29% of respondents' total daily energy intake. Still, the analysis did not show a significant relationship with the incidence of diabetes mellitus. This result may reflect the study's cross-sectional design, which precluded a definitive causal relationship between UPF consumption and the development of diabetes mellitus. Previous longitudinal research has shown that UPF consumption affects the development of diabetes mellitus [27].

The high intake of UPFs in this study was observed not only in the diabetic group (30.46%) but also in the non-diabetic group (29.89%). This study reflects the dietary transition in modern society from consuming whole foods to ultra-processed foods, which are synonymous with processed and ready-to-eat foods. This change in consumption patterns has been documented

globally as part of a dietary transition that is often occurring in urban areas [12, 29]. This phenomenon has important implications for public health, considering that long term, high consumption of ultra-processed foods can trigger clinical manifestations of various metabolic disorders and contribute to a decline in people's quality of life [28]. In line with existing scientific evidence, public health policies related to UPFs, such as more informative food labeling and price adjustments, are becoming increasingly relevant and need to be prioritized. However, the food industry is expecting to continue producing UPFs because these products meet consumer needs for practicality and taste. Therefore, efforts to increase consumer awareness of healthy eating patterns and to encourage them to review food product choices based on their health needs are crucial.

## Conclusions

In this study, 30.7% of respondents had diabetes mellitus, with an obesity nutritional status of 16.0% based on the waist-to-hip ratio. The waist-to-hip ratio is associated with the incidence of diabetes mellitus (p=0.01). The waist-to-hip ratio indicator is a more relevant obesity index for predicting the incidence of diabetes mellitus (AUC=0.76). Ultra-processed food intake accounted for 30.29% of total daily energy, but no significant relationship was found between ultra-processed food intake and the incidence of diabetes mellitus (p=0.077). Given the cross-sectional design of this study, a causal relationship between ultra-processed food consumption and the incidence of diabetes mellitus cannot be concluded. Therefore, longitudinal research is needed to clarify the causal relationship between ultra-processed food consumption and changes in metabolic parameters in individuals with type 2 diabetes mellitus, and to fill the existing scientific evidence gap.

## Conflict of interest

The authors declare no conflict of interest.

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