Vol. 12, No. 1 (2025), pp.73–85

CHITKARA UNIVERSITY

Journal of Multidisciplinary Research in Healthcare

Anthropometric Measurements and Nutrient Intake Among Type 2 Diabetic Mellitus (T2DM) Patients with Poor Glycaemic Control: A Cross-sectional Survey

Kavita Kachhawa[1*], Sarla Lakhawat[2] and Rakesh Kumar Saini[3]

[1]*Department of Home Science, University of Rajasthan, Jaipur, Rajasthan, India.*

[2]*Department of Food Science and Nutrition, CCAS, MPUAT, Udaipur, Rajasthan, India.*

[3]*Department of General Medicine, SMS Medical College and Attached Hospitals, Rajasthan University of Health Sciences, Jaipur, Rajasthan, India.*

[*]kavitakachhawa15@gmail.com (Corresponding Author)

RESEARCH ARTICLE **Open Access**

ARTICLE INFORMATION

Received: January 09, 2026
Accepted: April 15, 2026
Published Online: May 15, 2026

Keywords:
Type 2 diabetic mellitus, Poor glycaemic control, Dietary pattern, Nutrient intake

DOI: 10.15415/jmrh.2025.121009

ABSTRACT

Background: Effective dietary control is fundamental to managing hyperglycaemia in Type 2 Diabetes Mellitus (T2DM), due to its strong impact of nutrition on metabolic health. Persistent chronic hyperglycaemia (HbA1c ≥ 6.5%) in T2DM individuals despite taking regular medication is quite common and may be a reflection of their adopted dietary pattern and existing nutritional status.
Purpose: Assessment of diabetes-related information, anthropometric measurements, and food intake of T2DM patients with hyperglycaemia (i.e., HbA1c ≥ 6.5%) may help to elucidate their dietary approaches for T2DM management and reasons for elevated blood glucose levels.
Methods: A sample size of 60 T2DM patients with uncontrolled blood sugar (HbA1c ≥ 6.5%) was selected by purposive sampling. Background information, diabetes-related information, anthropometric information, diabetes history, food consumption pattern, and dietary intake were collected by direct interview.
Results: The findings of the present study revealed that the mean age of participants was 51.87 ± 10.92 years with a mean HbA1c level of 8.75%. The mean BMI and WHR were 25.25 ± 4.30 kg/m² and 0.96, respectively, indicating the risk of diabesity. The average daily intake of fats and milk products was high, while cereals, pulses, green leafy vegetables, roots and tubers, other vegetables, and sugars were below the reference levels. Participants tended to reduce their energy intake (1747.51 ± 369.71 kcal/day). Micronutrient intake such as Ca, Fe, Zn, vitamin A, riboflavin, and niacin was found to be approximately half of the reference values.
Conclusions: T2DM patients with uncontrolled blood glucose levels (i.e., HbA1c ≥ 6.5%) showed high BMI and WHR, with a staple wheat-based diet and low consumption of fruits and vegetables. Macronutrient intake was sufficient except for fat, while micronutrient intake requires attention.

1. Introduction

The increasing prevalence of diabetes mellitus is a global concern, and developing countries like India require more attention, as every fourth diabetic in the world is an Indian (International Diabetes Federation, 2025). The increasing pace of diabetes in India is reflected by 101 million diabetics and 136 million prediabetics (Anjana *et al.*, 2023). Of all the reported cases of diabetes, type 2 diabetes mellitus (T2DM) accounts for approximately 90–95%, mostly attributed to the interplay of various genetic, metabolic, environmental, and lifestyle factors (Galicia-Garcia *et al.*, 2020). The high risk of T2DM among Indians is due to the Asian Indian phenotype, characterized by unique clinical and biochemical parameters such as high insulin resistance; greater abdominal adiposity despite low body mass index (BMI); low adiponectin and high-sensitivity C-reactive protein. These, together with the dyslipidaemia triad (low high-density lipoprotein [HDL], high low-density lipoprotein [LDL], and high triglycerides), make Indians more susceptible to developing T2DM (Unnikrishnan *et al.*, 2014; Indian Council of Medical Research, 2018). The gender distribution of T2DM is quite equal in India, and the incidence peaks mostly around 55 years of age (Khan *et al.*, 2020). The prevalence of diabetes in males (15.56%) is slightly higher than in females (13.5%) (Indian Institute of Population Sciences & ICF International, 2021). The urban prevalence (19.5%) is comparatively higher than rural prevalence (15%), mainly due to a more sedentary lifestyle and consumption of refined foods (Anjana *et al.*, 2017).

Measurement of acute (fasting and postprandial blood glucose level) and chronic (glycated hemoglobin—HbA1c) glycaemic levels are universally accepted indicators for the diagnosis and management of diabetes. After diagnosis, regulation of blood glucose levels is crucial for preventing chronic complications of T2DM. HbA1c is a measure of chronic glucose levels, reflecting the integrated mean glucose level of the previous 8–12 weeks, also corresponding to erythrocyte lifespan (Sherwani *et al.*, 2016). An HbA1c level of ≥ 6.5% (48 mmol/mol) is equal to random blood sugar levels ≥ 11.1 mmol/L (200 mg/dL) and is recommended as the cut-off for diagnosing diabetes and can be used as a reliable indicator of long-term quality care available to the diabetic population (World Health Organization, 2011; American Dietetic Association, 2016; Unnikrishnan *et al.*, 2014).

Prevention, early diagnosis, and prompt treatment of hyperglycaemia in diabetic patients are the cornerstones for the prevention of chronic complications. The prolonged state of hyperglycaemia (elevated blood glucose levels, HbA1c ≥ 6.5%) in the population with diabetes is also a dependent and independent causative factor for other non-communicable diseases by adversely affecting cardiovascular, gastrointestinal, and genitourinary systems, contributing to related morbidity and mortality (Forbes & Cooper, 2016; Bandey *et al.*, 2020). If the HbA1c level increases from < 6.5% to 7.4% and ≥ 11.5%, the mortality risk increases by 31% and 40%, respectively (Anyanwagu *et al.*, 2019). In patients with diabetes, symptoms of severe long-term hyperglycaemia include polyuria, polydipsia, polyphagia, weight loss, and blurred vision. Impairment of growth and susceptibility to certain infections may also accompany chronic hyperglycaemia (American Diabetes Association, 2022). T2DM patients with prolonged hyperglycaemia may develop short-term metabolic dysfunctions and long-term vascular complications affecting both micro- and macrovascular systems.

Multiple Indian studies present strong evidence about the suboptimal management of diabetes in the Indian diabetic population. The ICMR INDIAB-13 study reports that only 7% of diabetic Indian individuals meet treatment targets for blood glucose, lipids, and blood pressure, and the proportion is likely to be even lower among those with undiagnosed diabetes (Anjana *et al.*, 2022). Over 50% of individuals with diabetes in India have poor glycaemic control (HbA1c > 8%), uncontrolled hypertension, dyslipidaemia, and vascular complications (Muralidharan, 2024). Even after regular medication, 72.7% of patients tested have HbA1c levels above 7% (Joshi *et al.*, 2014). Thus, chronic hyperglycaemia in T2DM is a well-reported issue among the Indian diabetic population.

Several factors such as low educational attainment, high BMI and waist–hip ratio (WHR), poor drug adherence, sedentary lifestyle, unhealthy life choices, higher stress level, and non-vegetarian diet are found to be associated with poor glycaemic control in T2DM (Kumari *et al.*, 2025; Rajan *et al.*, 2024). Among these factors, diet is crucial, as it has a direct effect on blood glucose levels. Higher consumption of total fat, saturated and monounsaturated fatty acids, and protein, and lower consumption of dietary fibre are associated with poor glycaemic control in diabetic individuals (Xu *et al.*, 2007). The staple wheat-based diet is also found to have a detrimental effect on diabetic subjects (Raghuram *et al.*, 2021). Moreover, micronutrient deficiencies result in difficulties in regulating blood sugar and insulin resistance (Iatcu *et al.*, 2024). To improve metabolic control, diabetic individuals generally follow guided or self-imposed dietary restrictions, which alter their dietary habits and may lead to nutritional deficiencies. Thus, assessment of dietary intake of diabetic patients with poor glycaemic control (HbA1c ≥ 6.5%) may provide a comprehensive understanding of their dietary habits and nutrient intake and suggest effective strategies for their dietary management. Evidence suggests that adoption of proper lifestyle modifications and dietary management may delay, prevent, or even remit T2DM (Rosenfeld *et al.*, 2022).

The state of Rajasthan has a lower prevalence of T2DM (10%) compared to the national prevalence due to its diet diversity based on local fruits and whole grains, with low exposure to smoking (Chauhan *et al.*, 2025). However, the state capital, Jaipur, accounts for a higher prevalence of T2DM, i.e., 15% (NFHS, 2019), mainly due to its urban lifestyle. Diet plays a crucial role in diabetes management and has a direct impact on associated hyperglycaemia. Although numerous studies have identified the relationship between diet and diabetes prevalence, there is still a paucity of studies exploring the actual consumption of food groups and nutrient intake among T2DM patients who have long-term poor glycaemic control even after regularly consuming hypoglycaemic medications. Thus, this study aims to assess diabetes-related information, anthropometric measurements, dietary pattern, food groups consumption and nutrient intake among T2DM individuals who have long-term poor glycaemic control, reflected by HbA1c level ≥ 6.5%.

2. Methodology

- **Ethical approval:** The research study was approved by the Institutional Ethical Committee for Human Research, Maharana Pratap University of Agriculture and Technology, Udaipur.
- **Study design:** Cross-sectional descriptive study
- **Study locale:** Approval of the institutional ethical committee was obtained prior to study commencement. Persons within the age group of 30-60 years and above

attending the Medical OPD, RK Hospital, Jaipur were included in this study.

- **Sample size:** A general rule of thumb in descriptive studies is to take 30 patients or greater to estimate a parameter. A sample of 60 T2DM patients was selected based on the general rule of thumb and ethical committee recommendation. The sample size of the present study corresponds to the calculated sample size of 52 or more measurements to have a confidence level of 85% and within ±10% margin of error.
- **Sampling technique:** A sample of 60 T2DM patients [(males; n_1=36) and (females; n_2=24)] was selected by purposive sampling.
- **Inclusion criteria:**
  - Having an HbA1c level ≥ 6.5%.
  - Aged between 30-60 Years
  - Willing to participate
  - Diagnosed with a clinical history of T2DM for a minimum of three years
  - Taking regular medication to control hyperglycaemia
  - Moderate Physical activity level
  - Have no change in the medical treatment of diabetes from the last six months
- **Exclusion criteria:**
  - Having severe illness.

- **Data collection:** After obtaining proper consent, participants were interviewed personally by using a structured questionnaire for the following information-
  - **Background information:** Age, marital status, education, occupation, family income, and family size were collected. The socioeconomic status of the participants was determined on the basis of education, occupation and family income using the modified Kappuswamy Socio-Economic Status Scale 2021 (Saleem & Jain, 2021).
  - **Anthropometric measurements:** Weight, height, waist, and hip circumference were collected, and BMI [weight(kg)/height^2(m^2)] and WHR [waist circumference (cm)/hip circumference (cm)] were calculated (Jelliffe,1966).
  - **Blood glucose levels:** Fasting and postprandial blood glucose were measured using the GOD/POD method (Dandekar & Rane, 2004; Trinder, 1969). The direct HbA1c was measured by nephelometry (Prathima *et al*, 2020). Average blood sugar was calculated on the basis of HbA1c (Garg *et al*, 2022).
  - **Dietary intake:** Information on meal patterns, consumption patterns of food groups, nutritive and non-nutritive substances was collected. Average consumption of food groups and nutrient intake were collected using the 24-hour recall method from each participant (Longyah *et al*., 2017; Bamji *et al*., 2019). The average daily nutrient intake of diet was calculated by using Dietsoft software. The Dietsoft software calculates the nutrient intake based on Indian Food Composition Tables (IFCT) given by Longvah *et al*. (2017). The percentage adequacy was also determined by comparing the average nutrient intake of participants with the recommended dietary allowance (RDA) for their gender, age and physical activity (Indian Council of Medical Research, 2020) for all nutrients.
- **Statistical analysis:** Data were presented as frequencies, mean±standard deviations (SD). The Karl Pearson correlation between anthropometric measurements and HbA1c levels was analysed at the 5% significance level.

3. Results

Data from Table 1 and Figure 1 indicated that the majority of the participants have: age >50 years (63.33%); males (60%); married (83.33%); educated more than 10th class (56.67%); working in the unorganised sector (75%), and middle-class socio-economic status (56.67%). The mean age of participants is 51.87±10.02 years, with a known history of diabetes for the last ten years (41.93±8.45 years).

Table 1: Background Information

S. No.	Particulars	Values (Mean ± SD)
1.	Mean age (Years)	51.87±10.92
2.	Mean age of diagnosis of diabetes (Years)	41.93±8.45
3.	Mean socioeconomic status score	16.82±6.57
4.	Average number of Family Members	5.02±2.21

Table 2: Medical Treatment of T2DM

S. No.	Particulars	Frequency % (n)
1.	**Frequency of Consultation**	
	Bimonthly	05.00 (03)
	Monthly	40.00 (24)
	Quarterly	33.33 (20)
	Biyearly	20.00 (06)
	Once a Year	11.67 (07)

2.	**Medication**	
	Regular consumption of medication	91.67 (55)
	Metformin (500mg) BD	18.33 (11)
	Metformin 500mg BD with combinations	68.33 (41)
	Insulin	5.00 (03)

3.	**Pre-existing Comorbidities**	
	Hypertension	16.67 (10)
	Obesity	26.67 (16)
	Hypercholesterolemia	1.67 (1)
	Heart attack	1.67 (1)
	Any other	11.67 (7)

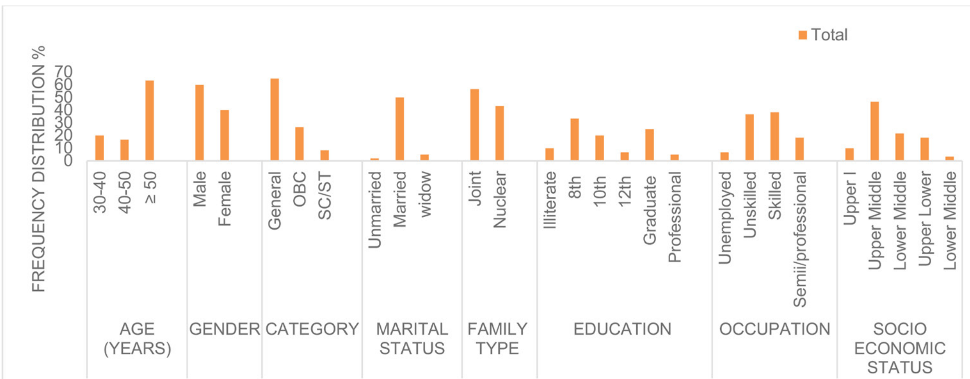

Figure 1: Background Information

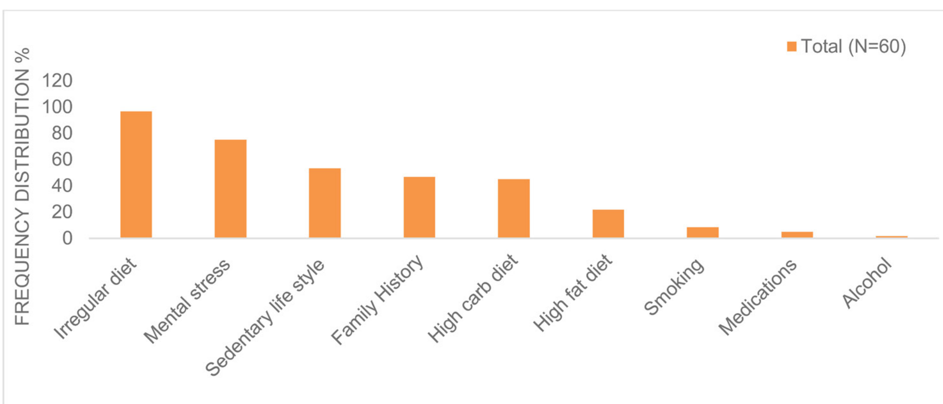

Figure 2: Perceived Reasons of T2DM Onset

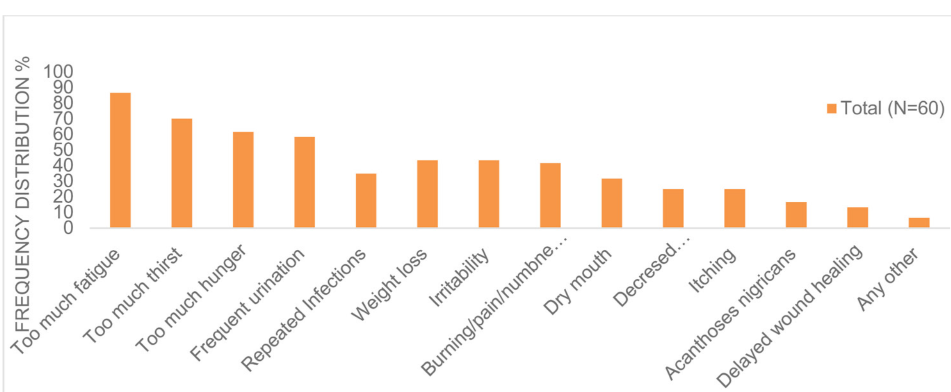

Figure 3: Felt Symptoms After T2DM Onset

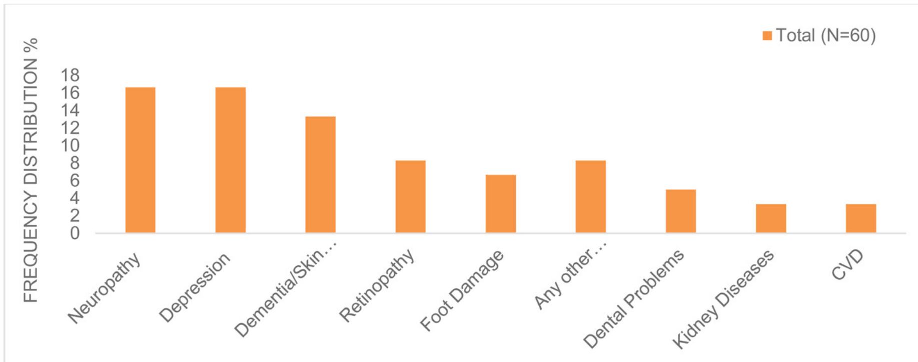

Figure 4: Diabetes Associated Complications After T2DM Onset

Table 3: Anthropometric Measurements, Blood Pressure and Blood Glucose Level.

S. No.	**Particulars**	**Males (n1=36)** Mean ± SD	**Females (n2=24)** Mean ± SD	**Total (n=60)** Mean ± SD	**Correlation (r) with HbA1c**
1.	**Anthropometric Measurements and Indices**				
	Weight	73.36±13.49	62.35±11.70	68.96±13.77	-0.0476^{NS}
	Height	169.69±7.18	157.85±3.18	165.01±8.32	-
	Waist circumference (cm)	90.55±11.01	88.13±10.41	89.58±10.66	0.0727^{NS}
	Hip circumference (cm)	92.67±8.64	95.28±12.84	93.71±9.82	-0.0147^{NS}
	BMI (kg/m^2)	25.43±4.19	25.03±4.69	25.25±4.30	0.0836^{NS}
	WHR	0.98±0.05	0.93±0.03	0.96±0.05	0.0162^{NS}
2.	**Blood Glucose Levels**				
	Fasting (mg/dl)	177.06±56.61	185.38±74.13	178.05±65.01	-
	Postprandial (mg/dl)	221.36±66.31	230.08±89.06	224.85±75.63	-
	HbA1c (%)	8.49±1.80	8.71±2.37	8.54±2.04	-
	Average blood sugar (mg/dl)	196.83±51.58	203.38±68.01	198.45±58.67	-

Note: NS = non-significant

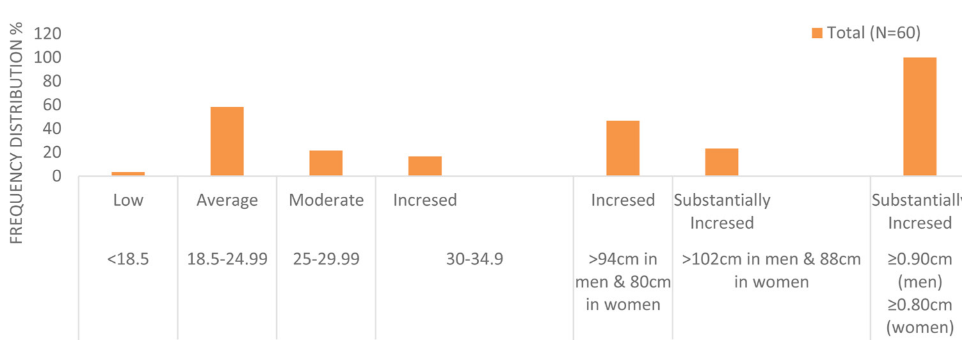

Figure 5: Anthropometric Measurements and Indices of T2DM Subjects

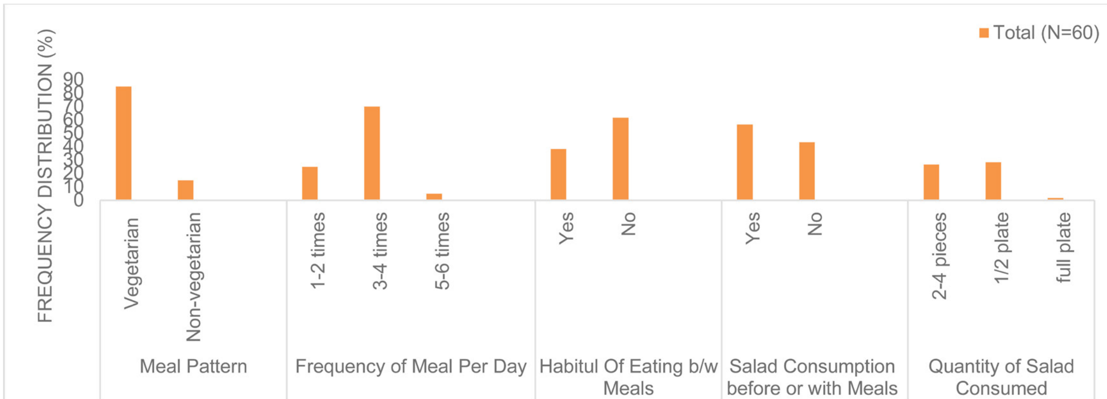

Figure 6: Meal Pattern of T2DM Subjects

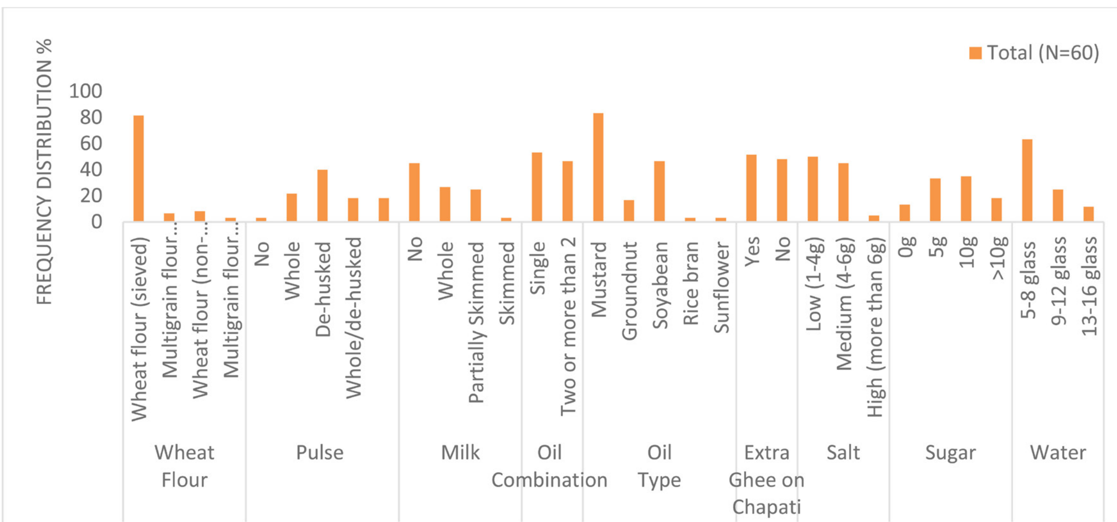

Figure 7: Consumption Pattern of Food Groups by T2DM Subjects

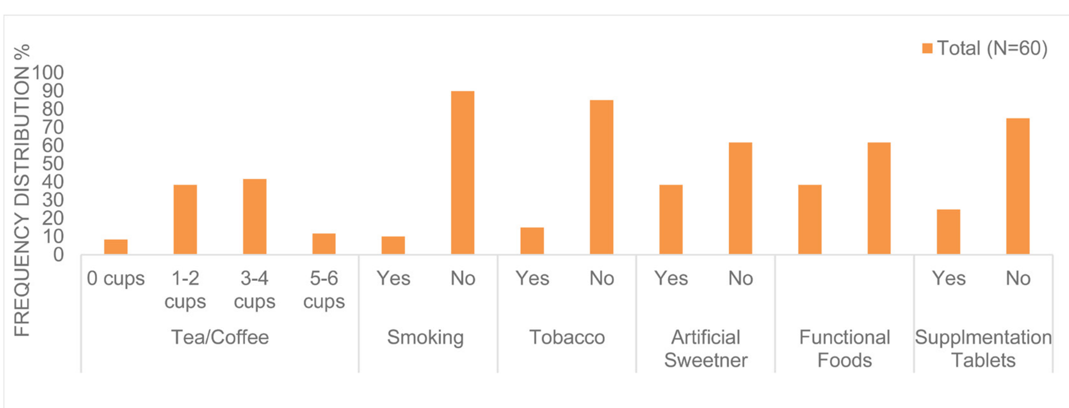

Figure 8: Consumption of Other Nutritive and Non-Nutritive Substances by T2DM Subjects

- **Diabetes-related information:** Data presented in Table 2 indicate that the majority of participants (86.67%) were regularly taking only metformin or its combinations with other active ingredients for T2DM management. It was found that obesity was the major pre-existing comorbidity (26.67%), followed by hypertension (16.67%). Data presented in Figure 2 highlighted that participants perceived their irregular diet (96.67%), mental stress (75%), family history of diabetes (63.33%), and sedentary lifestyle as major contributing factors in their diabetes onset. Fatigue (86.67%), along with polydipsia (70%), polyphagia (61.67%), and polyuria (58.33%), were symptoms most felt by the participants (Figure 3). The participants reported neurological problems (16.67%), depression (16.67%), skin infections (13.33%), and dementia (13.33%) as the most common associated complications after T2DM onset (Figure 4).

- **Anthropometric measurements and blood sugar level:** The findings given in Table 3 revealed that the mean weight (68.96 kg), waist circumference (89.58 cm), hip circumference (93.71 cm), BMI (25.25 kg/m^2), and waist-hip ratio (0.96) of all participants were comparatively higher than their reference cut-off given by Indian Council of Medical Research (2018). Data from Figure 5 revealed that 58.33% had a normal BMI, followed by overweight (21.67%), obese (16.67%), and underweight (3.33%). A total of 70% of participants had a waist circumference ≥ 94cm in men or ≥80cm in women. All the participants had a WHR of more than 0.90 in men or 0.80 in women, which indicates their substantially increased risk of comorbidities. However, none of anthropometric measurements showed significant correlation with HbA1c levels. The HbA1c level showed a weak positive correlation with waist circumference and WHR, while a weak negative correlation with weight and BMI.
- **Dietary Intake**
  - **Meal pattern:** Data from Figure 6 indicated that the majority of the participants follow vegetarian diet (85%), meal frequency 3-4 times a day (70%), and occasional consumption of salad before or with meal (56.67%).
  - **Consumption Pattern of Food Groups:** Data from Figure 7 revealed that consumption of sieved wheat flour (81.67%), use of mustard oil for cooking (83.33%), and moderate salt intake in food (95 %) were frequent. Table sugar consumption ≤10 g/day or nil was reported by 20% and 26.67% of the participants respectively. Only one fourth of the participants reported sufficient water intake (2-3 litres/day).
  - **Consumption pattern of other nutritive or non-nutritive substances:** Data from Figure 7, majority of the participants were taking 1-4 cups tea or coffee per day (80%), non-smoker (90 %), non-alcoholic (95 %), not taking guthkha, tobacco or paan (85 %) and not consuming any kind of artificial sweetener (93.33 %). For controlling hyperglycaemia, 38.33 % of participants were consuming functional foods. Majority of the respondents (75%) were not taking any kind of nutritional supplements.
  - **Average daily consumption of food groups:** Comparison of average daily food group consumption of all the participants (as given in Table 5) indicated that the people tend to reduce their average daily intake of cereals, pulses and legumes, other vegetables and sugars were reduced from the recommended values given in dietary guidelines for Indians (Indian Council of Medical Research, 2024). Consumption of fats and oils and milk & milk products was higher than their recommended values. The consumption of green leafy vegetables and roots and tubers was only one-fourth and one-third of the recommended values respectively.
  - **Average nutrient intake:** From the data given in Table 6, it is clear that the daily average energy intake of all the respondents was 1747.51±369.71 kcal, comprising contribution as 54% from carbohydrates (235.67±48.65 g); 28.65% from fats (55.63±24.83 g); 12.57% from protein (54.90±16.83 g); and 4.75% from dietary fibre (41.52±11.73 g) respectively. The intake of macronutrients by all the participants was similar to the dietary recommendation of Indian Council of Medical Research (2018) given for T2DM management, as the contribution of energy from carbohydrates (55-60%), fats (20-30%), protein (12-15%), and dietary fibre (40 g/day).
  - **Percentage adequacy of average nutrient intake:** From the data in Table 7, it is clear that all participants tend to reduce their energy intake and are at par with the recommended values. The percentage adequacy of protein and dietary fibre was quite comparable to the recommended values. Fat intake was approximately twice the recommended values. In micronutrients, intake of phosphorus, thiamine, and ascorbic acid were quite adequate. Among all the nutrients, the percentage adequacy of vitamin A, riboflavin, zinc and niacin was approximately half of the recommended values in both males and females.

Table 5: Average Daily Consumption of Food Groups

S. No.	Food Groups	Recommended Values (Indian Council of Medical Research, 2024)	Values (n=60) (Mean ± SD)
1.	Cereals & Millets (g)	250-320	235.88±71.14
2.	Pulses & Legumes (g)	85-105	43.11±33.86
3.	Milk & Milk Products (ml)	300	416.22±243.04
4.	Fats & oils (ml)	25-30	55±27.11
5.	Green Leafy Vegetables (g)	100	25.39±66.12
6.	Roots & Tubers (g)	200	67.44±72.38
7.	Other Vegetables (g)	200	178.90±132.89
8.	Fruits (g)	100	118.31±174.50
9.	Nuts & Oilseeds (g)	30-40	2.20±7.38
10.	Sugars (g)	20	8.36±10.14
11.	Eggs (g)	-	7.67±36.72
12.	Poultry (g)	-	10.89±46.46

Table 6: Nutrient Intake

S. No.	Particulars	Males (n1=36)	Females(n2=24)	Total (n=60)
		Mean ± SD		
1.	Energy (kcal)	1828.61±390.46	1625.36±295.40	1747.51±369.71
2,	Carbohydrates (g)	246.64±45.36	218.83±49.01	235.67±48.65
3,	Dietary fibre (g)	43.55±23.36	38.35±22.21	41.52±11.73
4,	Protein (g)	57.79±18.61	50.46±12.62	54.90±16.83
5.	Fat (g)	58.66±28.94	51.2±16.19	55.63±24.83
6.	Minerals (g)	2.80±2.01	2.60±1.36	2.72±1.76
7.	Calcium (mg)	666.03±234.69	597.28±187.50	637.24±243.88
8.	Phosphorus (mg)	1510.89±326.69	1339.41±292.95	1442.86±325.36
9.	Iron (mg)	16.18±4.73	14.67±3.97	15.59±4.49
10.	Zinc (mg)	9.47±2.39	8.22±1.92	8.98±2.27
11.	Vitamin A (μg)	338.84±525.93	387.76±457.33	353.33±453.63
12.	Thiamine (mg)	1.55±0.35	1.36±0.29	1.47±0.36
13.	Riboflavin (mg)	0.97±0.31	0.90±0.28	0.95±0.29
14.	Niacin (mg)	9.83±5.31	8.37±3.20	9.25±4.99
15.	Folic acid (μg)	258.18±142.60	217.08±94.40	241.06±126.84
16.	Vitamin C (mg)	115.06±166.59	87.41±79.84	103.90±138.66

Table 7: Percentage Adequacy of Average Daily Nutrient Intake

	Recommended Values (Indian Council of Medical Research, 2020)		Total (n=60)	
Nutrients	Men	Women	Male (n1=36)	Female (n2=24)
Energy (Kcal)*	1834	1560	99.71	104.19

Energy (Kcal)	2110	1660	86.67	97.91
Protein (g)	54	46	107.02	109.66
Fat (g)	30	25	195.53	204.80
Dietary fibre (g)	40	30	108.86	127.83
Calcium (mg)	1000	1000	66.60	59.73
Phosphorus (mg)	1000	1000	142.36	133.94
Iron (mg)	19	29	85.16	50.59
Zinc (mg)	17	13.2	55.70	48.35
Vitamin A (µg)	1000	840	33.88	46.16
Thiamine (mg)	1.8	1.7	86.11	80
Riboflavin (mg)	2.5	2.4	38.8	37.5
Niacin (mg)	18	14	54.61	59.79
Folic acid (µg)	300	220	86.06	98.67
Vitamin C (mg)	80	65	143.83	134.48

Note: *Energy calculated for T2DM subjects (25kcal/kg mean body weight) as recommended by Indian Council of Medical Research (2018).

4. Discussion

Insulin resistance and impaired insulin secretion in T2DM result in a noteworthy acute rise of fasting and postprandial blood glucose levels. And, if unregulated for an extended time period, leads to chronic hyperglycaemia (HbA1c > 6.5%), which further increases the risk of several macro- and microvascular complications (Yu *et al.*, 2025). Similar to the findings of the present study, studies reported that even after the regular use of hypoglycaemic drugs, more than 80% of T2DM individuals have HbA1c ≥ 7%, BMI ≥ 25 kg/m², and waist circumference ≥ 85 cm in females and ≥ 90 cm, indicating the risk of diabesity (Joshi *et al.*, 2014; Unnikrishnan *et al.*, 2014). Suvarna *et al.* (2022) reported a high level of BMI (25.4 kg/m²), waist circumference (88.64 cm), and hip circumference (100.1 cm) in 212 T2DM patients residing in South India. Bhati & Goyal (2013) also reported that diabetic males (n = 45; 74.5 kg) and females (n = 35; 68.5 kg) residing in Bikaner district of Rajasthan have more weight than the recommended values. Bhoi *et al*. (2021) also reported similar findings for weight (68.57 kg), BMI (26.41 kg/m²), and WHR (0.93) for 120 diabetic individuals residing in Ahmednagar, Maharashtra. Awasthi *et al*. (2017) also stated that BMI > 25 kg/m², abnormal waist circumference (≥ 90 cm in men or ≥ 80 cm in women), and abnormal WHR (0.9 in men or 0.85 in women) were seen in 55%, 74.5%, and 82.4% of T2DM patients of South India, respectively.

In the present study, T2DM subjects employed several self-dietary measures to manage their elevated blood glucose levels, such as consumption of mustard oil and functional foods. Literature supports such claims that the use of mustard oil in the diet may reduce blood glucose levels by improving insulin receptor signalling (Devi *et al.*, 2022). Functional foods intervention with a conventional hypoglycaemic drug can improve glycaemic control and prevent associated complications (Mirmiran *et al.*, 2014). A change in dietary pattern was also reported by Saaty and Ajadani (2024), with more inclusion of vegetables, green and leafy vegetables, starchy vegetables, fruits, proteins, and milk in the diet and avoiding consumption of sweets, sweetened juices, and soft drinks.

Findings of the present study highlighted that T2DM subjects reduced their energy consumption by 15–20% to maintain their blood glucose levels. Their consumption pattern indicates a skewed dietary pattern, with optimum carbohydrate and protein adequacy and high fat intake. The low intake of micronutrients such as calcium, iron, zinc, vitamin A, riboflavin, niacin, and folic acid was also observed. Consistent with the findings of the present study, T2DM individuals tend to lower their energy intake by 30% compared to the normal population, and half of the study participants reported deficient intake of micronutrients such as vitamins C, D, B12, and B9, zinc, calcium, magnesium, and copper. Joshi *et al*. (2014) also found that protein intake was adequate, but fat intake was high. The optimum macronutrient intake by T2DM may be due to the fact that Indian diets are majorly cereal-pulse-based vegetarian diets, which are high in calories but deficient in micronutrients (Sachdev & Misra, 2023). Micronutrient deficiencies including zinc (Naik *et al.*, 2019), potassium (Peng *et al.*, 2020), calcium (Itam *et al.*, 2022), magnesium (Kumar *et al.*, 2019), vitamin D (Monapati *et al.*, 2023), and vitamin B12 (Sayedali *et al.*) are commonly seen in T2DM and are associated with high glycated haemoglobin (HbA1c), a marker of long-term glycaemic control, and an increased risk of complications (Dubey *et al.*, 2020).

To improve glycaemic control, diabetic individuals generally follow guided or self-imposed dietary restrictions, which alter their dietary habits and may lead to nutritional deficiencies. Higher consumption of total fat, saturated and monounsaturated fatty acids, and protein, and lower consumption of dietary fibre are associated with poor glycaemic control in diabetic individuals (Xu *et al.*, 2007). The staple wheat-based diet is also found to have a detrimental effect on diabetic subjects (Raguram *et al.*, 2021). Moreover, micronutrient deficiencies such as vitamin D, E, C, magnesium, selenium, zinc, copper, iron, chromium, and iodine result in elevated blood sugar levels and insulin resistance (Iatcu *et al.*, 2024).

Supplements such as functional foods and micronutrients may modestly improve insulin sensitivity (Yu *et al.*, 2025). Since T2DM is a state of increased oxidative stress, antioxidant supplementation may improve diabetic management and reduce the risk of diabetic complications by improving insulin sensitivity, endothelial function, and glucose metabolism (Dilworth *et al.*, 2024). However, some studies have also contradicted this, stating that supplementation of vitamin C, vitamin E, and beta-carotene has no benefit with respect to improved glycaemic control and associated complications (Song *et al.*, 2009). Thus, there is still a need for more systematic evidence-based studies before prescribing any additional dietary and pharmaceutical supplementation to T2DM patients who have chronic hyperglycaemia (Petroni *et al.*, 2021).

5. Conclusion

Thus, from the findings of the present study, T2DM individuals with poor glycaemic control (HbA1c ≥ 6.5%) have high BMI and WHR, indicating the risk of central adiposity and associated comorbidities. The dietary pattern of T2DM individuals with poor glycaemic control is mainly reflected by a staple wheat-based diet, high fat intake, and low intake of micronutrients. The recommendation of a balanced diet approach, with special focus on reducing fat intake, inclusion of fibre-rich multigrain flour, and consuming more green leafy vegetables and raw vegetables, must be reinforced among T2DM subjects to prevent chronic hyperglycaemia and micronutrient deficiencies. Longitudinal studies with a large sample size and robust sampling are needed to understand the exact dietary pattern of Indians to prevent them from becoming the global diabetic capital of the world.

Acknowledgement

The authors declare that there are no acknowledgements for this study.

Authorship Contributions

Kavita Kachhawa: Conceptualization, Methodology, Data Collection, Data Analysis and Presentation, Writing – Review and Editing.
Sarla Lakhawat: Conceptualization, Methodology, Report Review.
Rakesh Kumar Saini: Conceptualization, Methodology, Data Collection.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical Approval

The present study was ethically approved by the Institutional Ethical Committee for Human Research, MPUAT, Udaipur, via Order No. 22/9897 dated 14/03/2022.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Declarations

The authors confirm that this manuscript is original, has not been published previously, and is not under consideration for publication elsewhere. The final version of the manuscript has been approved by all authors.

Data Availability Statement

The data supporting the conclusions of this study can be obtained upon reasonable request from the corresponding author (K K). The data are not publicly accessible due to confidentiality requirements and to protect the privacy of research participants.

Usage of Artificial Intelligence Statement

The authors acknowledge the use of AI-powered tools for preliminary drafting and ideation. However, all content was rigorously reviewed, interpreted, and refined by the authors to ensure scholarly integrity, originality, and full compliance with ethical and plagiarism standards.

Figure Permissions

No permission required. The authors declare that the entirety of the work, including text, figures, and tables, is original, has not been previously published, is in the public domain, or that the authors are the exclusive copyright holders.

References

American Diabetes Association. (2016). Standards of medical care in diabetes – 2016 abridged for primary care providers. *Clinical Diabetes, 34*(1), 3–21. https://doi.org/10.2337/diaclin.34.1.3

American Diabetes Association. (2022). Classification and diagnosis of diabetes: Standards of medical care in diabetes—2022. *Diabetes Care, 45*(Suppl. 1), S17–S38. https://doi.org/10.2337/dc22-S002

Anjana, R. M., Deepa, M., Pradeepa, R., Mahanta, J., Narain, K., Das, H. K., ... & Yajnik, C. S. (2017). Prevalence of diabetes and prediabetes in 15 states of India: results from the ICMR–INDIAB population-based cross-sectional study. *The lancet Diabetes & endocrinology*, *5*(8), 585-596. https://doi.org/10.1016/S2213-8587(17)30174-2

Anjana, R. M., Unnikrishnan, R., Deepa, M., Pradeepa, R., Tandon, N., Das, A. K., ... & Ghosh, S. (2023). Metabolic non-communicable disease health report of India: The ICMR-INDIAB national cross-sectional study (ICMR-INDIAB-17). *The Lancet Diabetes & Endocrinology, 11*(7), 474–489. https://doi.org/10.1016/S2213-8587(23)00119-5

Anjana, R. M., Unnikrishnan, R., Deepa, M., Venkatesan, U., Pradeepa, R., Joshi, S., ... & Joshi, S. R. (2022). Achievement of guideline recommended diabetes treatment targets and health habits in people with self-reported diabetes in India (ICMR-INDIAB-13): A national cross-sectional study. *The Lancet Diabetes & Endocrinology, 10*(6), 430–441. https://doi.org/10.1016/S2213-8587(22)00072-9

Anyanwagu, U., Mamza, J., Donnelly, R., & Idris, I. (2019). Relationship between HbA1c and all-cause mortality in older patients with insulin-treated type 2 diabetes: Results of a large UK cohort study. *Age and Ageing, 48*(2), 235–240. https://doi.org/10.1093/ageing/afy178

Awasthi, A., Rao, C. R., Hegde, D. S., & Rao, K. (2017). Association between type 2 diabetes mellitus and anthropometric measurements—A case control study in South India. *Journal of Preventive Medicine and Hygiene, 58*(1), E56. https://pubmed.ncbi.nlm.nih.gov/28515633/

Bamji, M. S., Krishnaswamy, K., & Brahmam, G. M. V. (2019). *Textbook of human nutrition* (4th ed.). Oxford & IBH Publishing Co. Pvt. Ltd.

Banday, M. Z., Sameer, A. S., & Nissar, S. (2020). Pathophysiology of diabetes: An overview. *Avicenna Journal of Medicine, 10*(4), 174–188. https://doi.org/10.4103/ajm.ajm_53_20

Bhati, K., & Goyal, M. (2013). Nutritional and health status of diabetic patients. *Studies in Home & Community Science, 7*(1), 45–48.

Chauhan, S., Khatib, M. N., Ballal, S., Bansal, P., Bhopte, K., Gaidhane, A. M., ... & Pant, M. (2025). The rising burden of diabetes and state-wise variations in India: insights from the Global Burden of Disease Study 1990–2021 and projections to 2031. *Frontiers in Endocrinology*, *16*, 1505143. https://doi.org/10.3389/fendo.2025.1505143

Dandekar, S. P., & Rane, S. A. (2004). *Practical and viva in medical biochemistry*. Elsevier.

Devi, P., Pandiyan, V., Tma, S., Kumar, G., & Krishnan, P. (2021). Dietary supplementation of mustard oil reduces blood glucose levels by triggering the insulin receptor signalling pathway. *International Journal of Diabetes in Developing Countries, 42*, 1–12. https://doi.org/10.1007/s13410-021-00952-6

Dilworth, L., Stennett, D., Facey, A., Omoruyi, F., Mohansingh, S., & Omoruyi, F. O. (2024). Diabetes and the associated complications: The role of antioxidants in diabetes therapy and care. *Biomedicine & Pharmacotherapy, 181*, 11764. https://doi.org/10.1016/j.biopha.2024.117641

Dubey, P., Thakur, V., & Chattopadhyay, M. (2020). Role of minerals and trace elements in diabetes and insulin resistance. *Nutrients, 12*(6), 1864. https://doi.org/10.3390/nu12061864

Forbes, J. M., & Cooper, M. E. (2013). Mechanisms of diabetic complications. *Physiological Reviews, 93*(1), 137–188. https://doi.org/10.1152/physrev.00045.2011

Galicia-Garcia, U., Benito-Vicente, A., Jebari, S., Larrea-Sebal, A., Siddiqi, H., Uribe, K. B., Ostolaza, H., & Martín, C. (2020). Pathophysiology of type 2 diabetes mellitus. *International Journal of Molecular Sciences, 21*(17), 6275. https://doi.org/10.3390/ijms21176275

Garg, P., Pethusamy, K., & Ranjan, R. (2022). Correlation between estimated average glucose levels calculated from HbA1c values and random blood glucose levels in a cohort of subjects. *Journal of Laboratory Physicians, 15*(2), 217–223. https://doi.org/10.1055/s-0042-1757719

Iatcu, O. C., Lobiuc, A., & Covasa, M. (2024). Micronutrient patterns and low intake of vitamin A, vitamin D, folate, magnesium, and potassium among prediabetes and type 2 diabetes patients. *Cureus, 16*(5), e60906. https://doi.org/10.7759/cureus.60906

Indian Council of Medical Research. (2018). *ICMR guidelines for management of type-2 diabetes 2018*. https://main.icmr.nic.in/sites/default/files/guidelines/ICMR_GuidelinesType2diabetes2018_0.pdf

Indian Council of Medical Research. (2020). *Nutrient requirements for Indians: Recommended dietary allowances and estimated average requirements*. Ministry of Health and Family Welfare. https://www.scribd.com/document/526073382/RDA-2020-Full-Ver

Indian Council of Medical Research. (2024). *Dietary guidelines for Indians: A manual*. National Institute of Nutrition. https://nin.res.in/dietaryguidelines/pdfjs/locale/DGI_2024.pdf

Indian Institute of Population Sciences & ICF International. (2021). *National Family Health Survey (NFHS-5), 2019–21: India report*.

International Diabetes Federation. (2025). *IDF diabetes atlas* (10th ed.). https://diabetesatlas.org/resources/idf-diabetes-atlas-2025/

Itam, A. H., Ogarekpe, Y. M., Edem, B., Agboola, A. R., Okpara, H. C., & Okokon, E. O. (2022). Association between serum calcium concentration and glycated haemoglobin in type II diabetic Nigerian patients. *BIOMED Natural and Applied Science, 2*(3), 2532. https://doi.org/10.53858/bnas02032532

Jelliffe, D. B. (1966). *The assessment of nutritional status of the community*. World Health Organization.

Joshi, S. R., Bhansali, A., Bajaj, S., Banzal, S. S., Dharmalingam, M., Gupta, S., ...& Joshi, S. S. (2014). Results from a dietary survey in an Indian T2DM population: A STARCH study. *BMJ Open, 4*(10), e005138. https://doi.org/10.1136/bmjopen-2014-005138

Kumar, P., Bhargava, S., Agarwal, P. K., Garg, A., & Khosla, A. (2019). Association of serum magnesium with type 2 diabetes mellitus and diabetic retinopathy. *Journal of Family Medicine and Primary Care, 8*(5), 1671–1677. https://doi.org/10.4103/jfmpc.jfmpc_83_19

Kumari, R., Singh, N., Karoli, R., Kandpal, S. D., Singh, S., & Ansari, A. (2025). Glycemic control and associated factors among type 2 diabetes mellitus patients at a tertiary health care facility. *Indian Journal of Community Health, 37*(2), 195–200. https://doi.org/10.47203/IJCH.2025.v37i02.004

Longvah, T., Ananthan, R., Bhaskarachary, K., & Venkaiah, K. (2017). *Indian food composition tables*. National Institute of Nutrition.

Mirmiran, P., Bahadoran, Z., & Azizi, F. (2014). Functional foods-based diet as a novel dietary approach for management of type 2 diabetes and its complications: A review. *World Journal of Diabetes, 5*(3), 267–281. https://doi.org/10.4239/wjd.v5.i3.267

Monapati, S., Kaki, P., Gurajapu, M. S., Subhas, P. G., & Kudipudi, H. B. (2023). The effects of vitamin D on preventing hyperglycemia and a novel approach to its treatment. *Drugs and Drug Candidates, 2*(4), 923–936. https://doi.org/10.3390/ddc2040046

Muralidharan, S. (2024). Diabetes and current Indian scenario: A narrative review. *Journal of Diabetology, 15*(1), 12–17. https://doi.org/10.4103/jod.jod_93_23

Naik, S. K., Ramanand, S. J., & Ramanand, J. B. (2019). A medley correlation of serum zinc with glycemic parameters in T2DM patients. *Indian Journal of Endocrinology and Metabolism, 23*(2), 188–192. https://doi.org/10.4103/ijem.IJEM_7_19

Peng, Y., Zhong, G. C., Mi, Q., Li, K., Wang, A., Li, L., ... & Yang, G. (2017). Potassium measurements and risk of type 2 diabetes: a dose-response meta-analysis of prospective cohort studies. *Oncotarget*, *8*(59), 100603. https://doi.org/10.18632/oncotarget.21823

Petroni, M. L., Brodosi, L., Marchignoli, F., Sasdelli, A. S., Caraceni, P., Marchesini, G., & Ravaioli, F. (2021). Nutrition in patients with type 2 diabetes: Present knowledge and remaining challenges. *Nutrients, 13*(8), 2748. https://doi.org/10.3390/nu13082748

Prathima, M., Shridhar, R. S., Kalal, B., & Ramarajan, M. (2020). Estimation of glycated haemoglobin by nephelometry, ion exchange resin and high-performance liquid chromatography: A cross-sectional study. *Journal of Clinical and Diagnostic Research, 14*, BC01–BC04. https://doi.org/10.7860/JCDR/2020/44408.13968

Raghuram, N., Anand, A., Mathur, D., Patil, S. S., Singh, A., Rajesh, S. K., ... & Hongasandra, N. (2021). Prospective study of different staple diets of diabetic Indian population. *Annals of Neurosciences, 28*(3–4), 129–136. https://doi.org/10.1177/09727531211013972

Rajan, Y., Bhabhor, H., Kharde, A., Kakadiya, J., Varsadiya, K., & Damor, A. (2024). Poor glycaemic control and its risk factors among diabetes patients in an urban area of western India. *National Journal of Community Medicine, 15*(1), 47–55. https://doi.org/10.55489/njcm.150120243602

Rosenfeld, R. M., Kelly, J. H., Agarwal, M., Aspry, K., Barnett, T., Davis, B. C., ... & Karlsen, M. C. (2022). Dietary interventions to treat type 2 diabetes in adults with a goal of remission: An expert consensus statement.

American Journal of Lifestyle Medicine, 16(3), 342–362. https://doi.org/10.1177/15598276221087624

Saaty, A. H., & Aljadani, H. M. (2024). Comparison of food intake pattern of diabetic patients and healthy individuals in a sample of Saudi population: A case-control study. *BMC Public Health, 24*(1), 1590. https://doi.org/10.1186/s12889-024-19064-x

Sachdev, M., & Misra, A. (2023). Heterogeneity of dietary practices in India: Current status and implications for the prevention and control of type 2 diabetes. *European Journal of Clinical Nutrition, 77*(2), 145–155. https://doi.org/10.1038/s41430-021-01067-1

Saleem, S. M., & Jan, S. S. (2021). Modified Kuppuswamy socioeconomic scale updated for the year 2021. *Indian Journal of Forensic and Community Medicine, 8*(1), 1–3. https://doi.org/10.18231/j.ijfcm.2021.001

Sayedali, E., Yalin, A. E., & Yalin, S. (2023). Association between metformin and vitamin B12 deficiency in patients with type 2 diabetes. *World Journal of Diabetes, 14*(5), 585–593. https://doi.org/10.4239/wjd.v14.i5.585

Sherwani, S. I., Khan, H. A., Ekhzaimy, A., Masood, A., & Sakharkar, M. K. (2016). Significance of HbA1c test in diagnosis and prognosis of diabetic patients. *Biomarker Insights, 11*, BMI-S38440. https://doi.org/10.4137/BMI.S38440

Song, Y., Cook, N. R., Albert, C. M., Van Denburgh, M., & Manson, J. E. (2009). Effects of vitamins C and E and beta-carotene on the risk of type 2 diabetes in women at high risk of cardiovascular disease: A randomized controlled trial. *The American Journal of Clinical Nutrition, 90*(2), 429–437. https://doi.org/10.3945/ajcn.2009.27491

Suvarna, R., Nasir, M. A., Stanley, W., & Prabhu, M. M. (2022). Anthropometric indices and type 2 diabetes mellitus as a risk factor in predicting nonalcoholic fatty liver disease. *Indian Journal of Community Medicine, 47*(3), 386–390. https://doi.org/10.4103/ijcm.ijcm_1213_21

Trinder, P. (1969). Determination of glucose in blood using glucose oxidase with an alternative oxygen acceptor. *Annals of Clinical Biochemistry, 6*(1), 24–27. https://doi.org/10.1177/000456326900600108

Unnikrishnan, R., Anjana, R. M., & Mohan, V. (2014). Diabetes in South Asians: Is the phenotype different? *Diabetes, 63*(1), 53–55. https://doi.org/10.2337/db13-1592

World Health Organization. (2011). *Use of glycated haemoglobin (HbA1c) in diagnosis of diabetes mellitus: Abbreviated report of a WHO consultation*. https://apps.who.int/iris/handle/10665/70523

Xu, J., Eilat-Adar, S., Loria, C. M., Howard, B. V., Fabsitz, R. R., Begum, M., ... & Lee, E. T. (2007). Macronutrient intake and glycemic control in a population-based sample of American Indians with diabetes: the Strong Heart Study. *The American journal of clinical nutrition*, *86*(2), 480-487.

Yu, X., Liu, X., & Li, H. (2025). Nutrient metabolism and complications of type 2 diabetes mellitus: Implications for rehabilitation and precision care. *Frontiers in Nutrition, 12*, 1699259. https://doi.org/10.3389/fnut.2025.1699259