Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 09 July 2026
Revised 24 Aug 2026
Accepted 07 Sep 2026

Natural Resources for Human Health 2026, Vol. 6 (19s): 1154–1165

KEYWORDS:
type 2 diabetes; dietary habits; obesity; dyslipidaemia; nutrition counselling; Saudi Arabia

Dietary habits and cardiometabolic indicators among adults with type 2 diabetes in Al Ahsa

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ABSTRACT: Dietary adherence and meal composition are important aspects of type 2 diabetes management, yet their associations with cardiometabolic indicators remain insufficiently characterized in local clinical populations. This study assessed dietary practices and their associations with obesity and lipid abnormalities among adults with type 2 diabetes attending King Abdulaziz Hospital in Al-Ahsa, Saudi Arabia. Questionnaire responses collected between September 2023 and February 2024 were combined with clinical records obtained during the study period for 326 participants. Analyses included descriptive statistics, Mann–Whitney U tests with Holm correction, Pearson chi-square tests and crude odds ratios (ORs) with 95% confidence intervals (CIs). Obesity affected 54.3%, HbA1c was ≥9% in 54.6%, and 67.5% reported non-strict dietary adherence. Carbohydrate-rich meals were associated with low HDL cholesterol (OR 4.11, 95% CI 2.39–7.09; p<0.001), LDL cholesterol ≥3.4 mmol/L (OR 2.03, 95% CI 1.28–3.22; p=0.002), and triglycerides ≥1.7 mmol/L (OR 83.02, 95% CI 11.19–615.74; p<0.001), but not obesity (p=0.696). Non-strict adherence was associated with obesity (OR 5.10, 95% CI 3.07–8.47), low HDL cholesterol (OR 8.93, 95% CI 4.42–18.03), LDL cholesterol ≥3.4 mmol/L (OR 4.86, 95% CI 2.88–8.20), and triglycerides ≥1.7 mmol/L (OR 17.77, 95% CI 6.67–47.38; all p<0.001). Males had higher median BMI after Holm correction (p=0.002). Non-strict dietary adherence was associated with obesity and lipid abnormalities, whereas carbohydrate-rich meals were associated with lipid abnormalities but not obesity. These unadjusted cross-sectional associations support further investigation and do not establish causality

1. INTRODUCTION

Type 2 diabetes mellitus (T2DM) remains a major clinical and public health challenge in Saudi Arabia, contributing substantially to the burden of chronic disease and increasing demands on healthcare services [1]. The coexistence of obesity, physical inactivity, and unfavorable dietary practices presents additional challenges for diabetes prevention and long-term management. Although glycemic control is a central component of diabetes care, comprehensive management requires consideration of

multiple interrelated factors, including nutritional status, dietary behaviors, physical activity, lipid abnormalities, and adherence to recommended lifestyle modifications [2].

Medical nutrition therapy is a cornerstone of T2DM management and emphasizes individualized dietary approaches that consider nutritional requirements, cultural food preferences, metabolic goals, and patients' ability to sustain dietary changes [3]. Contemporary diabetes management recommendations prioritize overall dietary quality, appropriate portion sizes, fiber-rich foods, and individualized eating patterns rather than a universally prescribed macronutrient distribution [2]. Evidence from systematic reviews indicates that higher dietary fiber intake may improve glycemic control and selected lipid parameters among adults with diabetes [4]. Nevertheless, dietary frequency questionnaires primarily describe reported eating behaviors and cannot independently establish nutrient intake, dietary quality, or the physiological effects of individual foods. An umbrella review of randomized-trial meta-analyses also found that the effects of dietary approaches vary across metabolic outcomes and in certainty of evidence, supporting assessment of overall eating patterns rather than a single macronutrient label [5].

In addition to dietary composition, adherence to nutrition recommendations and regular physical activity are important components of diabetes self-management. Diabetes self-management education and support have been associated with improvements in patients' knowledge, self-care behaviors, and glycemic outcomes [6]. Current clinical recommendations further emphasize person-centered nutrition counselling, physical activity assessment, and individualized behavioral support [2]. However, adherence to dietary recommendations may be influenced by patients' understanding, motivation, socioeconomic circumstances, cultural practices, and capacity to maintain recommended behaviors. Self-reported dietary adherence provides useful information about perceived compliance but may not accurately reflect actual food consumption or sustained behavioral change. A multidisciplinary consensus report recommends diabetes self-management education and support as an ongoing component of care and emphasizes reducing barriers to referral and participation [7].

Cardiometabolic abnormalities, including obesity, dyslipidaemia, and inadequate glycemic control, frequently coexist among adults with T2DM. Contemporary recommendations emphasize integrated weight management and individualized interventions to address obesity-related metabolic complications [8]. Investigating relationships between dietary practices and cardiometabolic indicators may help identify priorities for individualized nutrition counselling and patient education. However, cross-sectional associations should be interpreted cautiously because dietary behaviors, metabolic measurements, and treatment-related factors may influence one another, and temporal relationships cannot be established.

Despite the importance of nutrition in diabetes management, locally relevant assessments of dietary practices and their relationships with cardiometabolic indicators remain valuable for informing clinical nutrition services in Saudi healthcare settings. Therefore, the present hospital-based study aimed to describe self-reported dietary practices, food-group consumption, physical activity, glycemic indicators, and selected cardiometabolic characteristics among adults with T2DM receiving care at King Abdulaziz Hospital in Al-Ahsa, Saudi Arabia. It further examined associations of reported dietary adherence and carbohydrate-rich meal consumption with obesity and lipid abnormalities and compared selected continuous clinical and biochemical measurements between female and male participants. The study evaluated individual cardiometabolic indicators rather than cardiovascular events or a validated cardiovascular risk score. Previous Saudi research has identified distinct dietary patterns among adults with T2DM in Riyadh and reported limited adherence to dietary and exercise self-care in a tertiary-care setting [9,10]. These findings provide local context while differences in populations and assessment methods limit direct comparison.

2. MATERIALS AND METHODS

2.1 Study design and setting

A descriptive cross-sectional study was conducted at King Abdulaziz Hospital, Al-Ahsa, Eastern Province, Saudi Arabia, within the Ministry of National Guard Health Affairs system. Primary questionnaire information was combined with secondary clinical information from the electronic medical record accessed through the KAIMRC data management system.

2.2 Participants and sampling

The study used purposive sampling of Saudi adults with physician-diagnosed T2DM receiving care at King Abdulaziz Hospital and residing in Al-Ahsa or the Eastern Province. The respondents for study were ages 18–65 years and excluded non-residents and pregnant or lactating women. A minimum sample of 326 was estimated from 2,126 registered cases using the Raosoft

calculator with 95% confidence and a 5% margin of error. The target was increased to 359 to allow for non-response, and 326 complete responses were analyzed (90.8%). Because sampling was purposive, the nominal margin of error does not establish population representativeness.

2.3 Data collection and measurement

Dietary information was collected using a validated structured electronic questionnaire administered through Microsoft Forms between September 2023 and February 2024. Clinical and biochemical measurements, including HbA1c and lipid profiles, were retrieved from electronic medical records on or close to the dates of questionnaire completion during the same study period.

BMI was categorized as underweight (<18.5 kg/m²), normal weight (18.5 to <25), overweight (25 to <30), obesity class I (30 to <35), and obesity class II (35 to <40). Obesity for association analyses was BMI ≥30 kg/m². Activity was self-classified as active, moderately active, or sedentary. Strict dietary adherence and carbohydrate-rich meals were binary variables coded 1 for yes and 2 for no in the final dataset. The meal-composition item represented perceived food composition; it did not quantify carbohydrate intake or distinguish refined from whole-grain sources.

HbA1c was grouped as <7%, 7 to <9%, and ≥9%, for descriptive purposes. Low HDL cholesterol was defined as <1.03 mmol/L in males and <1.29 mmol/L in females. LDL cholesterol categories were <2.6, 2.6 to <3.4, and 3.4 to <4.1 mmol/L. Triglycerides were grouped as <1.7, 1.7 to <2.3, and 2.3 to <5.6 mmol/L. Association outcomes used LDL cholesterol ≥3.4 mmol/L and triglycerides ≥1.7 mmol/L. Food-group frequency responses were reported as not eaten, 1–2, 2–3, or 3–4 times per day.

2.4 Statistical analysis

Data were analyzed using IBM SPSS Statistics version 22. Categorical variables were summarized as frequencies and percentages, and continuous variables were described using appropriate measures of central tendency and dispersion. Comparisons of continuous variables between female and male participants were performed using the Mann–Whitney U test, with Holm adjustment for multiple comparisons. Associations between dietary practices and categorical cardiometabolic outcomes were examined using Pearson's chi-square test. Crude odds ratios and log-Wald 95% confidence intervals were reported for estimable binary associations. All comparisons in Table 5 used Pearson's chi-square test without continuity correction because expected cell frequencies exceeded five. Statistical significance was assessed at a two-sided p-value below 0.05. Given the exploratory nature of the analyses, the absence of multivariable adjustment, and sparse cells in selected comparisons, findings were interpreted cautiously.

2.5 Ethics

Ethical approval was obtained from the King Abdullah International Medical Research Center (KAIMRC)(NRA23A/029/07) Institutional Review Board (IRB/1990/23). Electronic informed consent was obtained from all participants. Data were anonymized and stored securely with restricted access.

3. RESULTS AND DISCUSSION

3.1 Participant characteristics and nutritional care needs

The present study included 326 adults with T2DM, with a mean age of 59.58 ± 5.08 years and a slightly higher proportion of females (54.6%) than males (45.4%). The comparable median ages of females (61.80 years) and males (61.35 years), with no statistically significant difference ($p = 0.968$; Holm-adjusted $p = 1.000$), suggest a similar age distribution between sexes. Nearly half of the participants reported sedentary activity (45.7%), while 58.6% reported a family history of cardiovascular disease and 21.8% reported smoking. These findings highlight the coexistence of several behavioral and non-modifiable cardiovascular risk factors in this hospital-based population. Current diabetes care recommendations emphasize regular physical activity, smoking cessation, and individualized cardiovascular risk-factor management as essential components of comprehensive T2DM care [2,11].

Regarding dietary practices, non-vegetarian diets were reported by 76.1% of participants, carbohydrate-rich meals by 62.9%, and non-strict dietary adherence by 67.5%. These findings suggest potential opportunities to strengthen individualized dietary education and self-management support. However, a non-vegetarian dietary pattern does not necessarily indicate poor dietary quality, and carbohydrate-rich meal consumption cannot independently establish excessive carbohydrate intake or inadequate

glycemic management without information on portion sizes, carbohydrate sources, total energy intake, and overall dietary composition. Contemporary nutrition recommendations emphasize dietary quality, fiber-rich foods, appropriate portions, and culturally acceptable individualized eating patterns rather than universal carbohydrate restrictions [2,3]. Aljahdali and Bawazeer identified five dietary patterns in Saudi adults with T2DM, including patterns characterized by vegetables and olive oil, refined grains and sweets, dairy products and legumes, dates and beverages, and fruit [9]. Their findings illustrate the diversity of food combinations that a binary carbohydrate-rich meal question cannot capture.

Only 47.9% of participants reported receiving dietary counselling, whereas 67.5% reported non-strict dietary adherence. These findings indicate gaps in reported counselling exposure and dietary adherence within the study population, although the two proportions cannot establish a direct relationship between counselling and adherence. Previous systematic evidence has demonstrated that structured diabetes self-management education can improve glycemic outcomes, particularly when interventions provide sustained educational and behavioral support [6]. Recent clinical recommendations similarly emphasize individualized diabetes self-management education and support, ongoing nutritional assessment, and strategies that address barriers to behavioral change [2]. Nevertheless, the present study did not assess counselling frequency, duration, content, quality, or timing, and therefore cannot determine whether counselling influenced participants' dietary practices. These findings support the need for further evaluation of structured, culturally appropriate nutrition education and follow-up services among adults with T2DM in Saudi Arabia. Alhaiti et al. also reported poor adherence to diet and exercise self-care in a Saudi tertiary-care population [10]. This offers contextual support for investigating self-management barriers, although their validated self-care instrument differs from the binary adherence item used here. The DSMES consensus report further supports integrating ongoing education and medical nutrition therapy into routine diabetes care [7].

Table 1. Participant characteristics (N = 326)

Characteristic	Category	n (%)
Gender	Female	178 (54.6)
	Male	148 (45.4)
Education level	Illiterate	42 (12.9)
	Primary school	36 (11.0)
	Intermediate school	36 (11.0)
	High school	135(41.4)
	University	77 (23.6)
Physical activity	Active	78 (23.9)
	Moderately active	99 (30.4)
	Sedentary	149 (45.7)
Family history of CVD	No	135 (41.4)
	Yes	191 (58.6)
Smoking status	No	255 (78.2)
	Yes	71 (21.8)
Dietary pattern	Non-vegetarian	248 (76.1)
	Lacto-vegetarian (dairy, no eggs)	14 (4.3)
	Ovo-vegetarian (eggs, no dairy)	7 (2.1)
	Vegan (no animal products)	57 (17.5)

Characteristic	Category	n (%)
Dietary counselling	No	170 (52.1)
	Yes	156 (47.9)
Strict adherence to diabetic diet	No	220 (67.5)
	Yes	106 (32.5)
Meals high in	Carbohydrates	205 (62.9)
	Fat	14 (4.3)
	Protein	79 (24.2)
	Fiber	28 (8.6)

3.2 Food choices and the relevance of dietary quality

The present study demonstrated variations in reported food consumption patterns among adults with T2DM. Consumption 1–2 times per day was the most frequently reported category for vegetables, fruits and baked goods, meat, dairy products, and cereals and bread. Fiber-rich foods were consumed at this frequency by 52.5% of participants, whereas 19.6% reported no consumption of fiber-rich foods and 63.2% reported not consuming dried fruits and nuts (Table 2). These findings suggest potential gaps in dietary diversity and the inclusion of fiber-containing foods, although food-frequency data alone cannot establish nutritional adequacy or compliance with recommended dietary intake.

Dietary quality is an important component of glycemic management and cardiovascular risk reduction in individuals with T2DM. Reynolds et al. [4], in a systematic review and meta-analysis, demonstrated that increased dietary fiber intake was associated with improvements in glycemic control and selected lipid parameters among individuals with diabetes. Similarly, the American Diabetes Association Standards of Care in Diabetes—2026 emphasize individualized dietary patterns incorporating nutrient-dense foods, vegetables, fruits, legumes, whole grains, and other fiber-rich food sources to support metabolic health [2]. The relatively high proportion of participants reporting no consumption of dried fruits and nuts may indicate an opportunity to encourage greater dietary variety, particularly through appropriate portions of unsalted nuts. However, dried fruits and nuts have different nutritional characteristics, and their combined assessment limits interpretation of individual food-group contributions.

Furthermore, the reported frequency of cereals, bread, and baked goods does not distinguish whole-grain products from refined carbohydrate sources. This distinction is clinically relevant because carbohydrate quality, fiber content, portion size, and overall dietary patterns may influence postprandial glycemic responses and long-term metabolic outcomes [2,3]. Although the present findings identify potentially important areas for nutrition counselling, the absence of quantitative dietary intake data prevents conclusions regarding total fiber consumption, energy intake, or the direct relationship between individual food groups and glycemic control. Future studies incorporating validated dietary assessment methods may provide a more comprehensive understanding of dietary quality and its association with cardiometabolic indicators among adults with T2DM in Saudi Arabia.

Table 2. Reported daily food group consumption frequencies (N = 326)

Food group	Not eaten n (%)	3–4 times/day n (%)	2–3 times/day n (%)	1–2 times/day n (%)
Vegetables	35 (10.7)	7 (2.1)	50 (15.3)	234 (71.8)
Fruits and baked goods	36 (11.0)	14 (4.3)	64 (19.6)	212 (65.0)
Cereals and bread	29 (8.9)	0 (0.0)	120 (36.8)	177 (54.3)
Dairy	42 (12.9)	7 (2.1)	92 (28.2)	185 (56.7)

Food group	Not eaten n (%)	3–4 times/day n (%)	2–3 times/day n (%)	1–2 times/day n (%)
Meat	56 (17.2)	7 (2.1)	64 (19.6)	199 (61.0)
Fatty foods	100 (30.7)	14 (4.3)	70 (21.5)	142 (43.6)
Fiber-rich foods	64 (19.6)	21 (6.4)	70 (21.5)	171 (52.5)
Sugary foods	92 (28.2)	29 (8.9)	50 (15.3)	155 (47.5)
Salty foods	86 (26.4)	14 (4.3)	58 (17.8)	168 (51.5)
Ice cream	219 (67.2)	0 (0.0)	7 (2.1)	100 (30.7)
Dried fruits and nuts	206 (63.2)	0 (0.0)	56 (17.2)	64 (19.6)
Sugar substitutes	164 (50.3)	21 (6.4)	28 (8.6)	113 (34.7)

3.3 Obesity, glycemic indicators, and sex comparisons

The present study revealed a substantial burden of obesity and unfavorable cardiometabolic indicators among adults with T2DM. Obesity was observed in 177 participants (54.3%), while an additional 71 (21.8%) were overweight, indicating that approximately three-quarters of the study population had excess body weight. Furthermore, 178 participants (54.6%) had HbA1c levels ≥9%, whereas only 50 (15.3%) had HbA1c levels below 7%. These findings suggest considerable challenges in weight management and glycemic control within this hospital-based population. Current diabetes management guidelines emphasize individualized weight management, medical nutrition therapy, physical activity, and appropriate pharmacological interventions to improve metabolic outcomes and reduce diabetes-related complications [2,8].

The lipid profile findings further highlight the importance of comprehensive cardiometabolic assessment. Low HDL cholesterol was observed in 35.6% of participants, while 48.2% had LDL cholesterol concentrations between 3.4 and less than 4.1 mmol/L, and 70.6% had triglyceride concentrations between 2.3 and less than 5.6 mmol/L. These abnormalities are clinically relevant because dyslipidaemia, obesity, and hyperglycaemia contribute to cardiovascular risk among individuals with T2DM. The American Diabetes Association Standards of Care—2026 recommend integrated management of cardiovascular risk factors, including lipid assessment, weight management, dietary modification, and individualized treatment strategies [11]. Nevertheless, the present study assessed individual biochemical indicators rather than cardiovascular events or validated cardiovascular risk scores; therefore, the findings should not be interpreted as direct estimates of future cardiovascular disease risk.

Sex-based comparisons demonstrated that males had a significantly higher median BMI than females (32.65 versus 28.85 kg/m²), with the difference remaining statistically significant after Holm correction (adjusted $p = 0.002$). This finding suggests that male participants in the present sample may require particular attention to weight-related nutritional assessment and individualized lifestyle interventions. However, the observed difference should not be interpreted as evidence of a sex-specific causal mechanism because potential contributing factors, including dietary intake, physical activity, medication use, and body composition, were not fully evaluated. Although triglyceride concentrations were initially higher among males (unadjusted $p = 0.021$), the association was no longer statistically significant following adjustment for multiple comparisons (adjusted $p = 0.124$). Similarly, no other continuous clinical or biochemical variables showed statistically significant sex differences after correction. These findings emphasize the importance of controlling for multiple testing to reduce the likelihood of false-positive conclusions.

Overall, the coexistence of excess body weight, elevated HbA1c, and unfavorable lipid indicators supports the need for comprehensive and individualized nutritional care among adults with T2DM. Integrating dietary assessment, weight management, physical activity counselling, and regular monitoring of glycemic and lipid parameters may help identify patients requiring more intensive multidisciplinary support [2,8,11]. However, the cross-sectional nature of the present study prevents determination of causal or temporal relationships between nutritional practices and cardiometabolic abnormalities.

The high proportion of participants with HbA1c ≥9% is particularly concerning because it indicates substantial hyperglycaemia in more than half of the sample. The ADA Standards of Care—2026 recommend an HbA1c target below 7% for many nonpregnant adults, while emphasizing that targets should be individualized according to age, comorbidities, functional status, and treatment-related risks [12]. Therefore, the relatively low proportion of participants with HbA1c below 7% (15.3%) highlights the importance of reviewing glycemic management and potential barriers to treatment adherence. However, the available data do not establish whether participants were failing to meet their individually prescribed glycemic targets.

The findings also have implications for clinical nutrition practice. Contemporary recommendations emphasize that weight reduction, when appropriate, can contribute to improvements in glycemic control and other metabolic risk factors among adults with T2DM [8]. Furthermore, dietary interventions that improve carbohydrate quality, reduce saturated fat intake, increase fiber consumption, and support sustainable weight management may contribute to improved lipid profiles [3,11]. The substantial proportion of participants with elevated triglycerides underscores the potential value of integrating nutrition counselling with pharmacological management and regular biochemical monitoring. Nevertheless, the absence of detailed information on medication use, diabetes duration, dietary intake, and treatment adherence limits interpretation of the factors contributing to these abnormalities. In the Direct cluster-randomized trial, a structured weight-management intervention in primary care produced diabetes remission in a substantial proportion of participants at 12 months [13]. This intervention evidence supports the clinical relevance of weight management, but it does not validate a causal interpretation of the present cross-sectional adherence–obesity association.

Table 3. Body mass index and biochemical categories overall and by sex (N = 326)

Measure	Category	Overall n (%)	Female n (%)	Male n (%)
BMI	Underweight (<18.5)	21 (6.4)	21 (11.8)	0 (0.0)
	Normal weight (18.5 to <25)	57 (17.5)	40 (22.5)	17 (11.5)
	Overweight (25 to <30)	71 (21.8)	30 (16.9)	41 (27.7)
	Obesity class I (30 to <35)	81 (24.8)	39 (21.9)	42 (28.4)
	Obesity class II (35 to <40)	96 (29.4)	48 (27.0)	48 (32.4)
HbA1c (%)	Below general target (<7%)	50 (15.3)	33 (18.5)	17 (11.5)
	7 to <9%	98 (30.1)	43 (24.2)	55 (37.2)
	≥9%	178 (54.6)	102 (57.3)	76 (51.4)
HDL cholesterol (mmol/L)	Low (<1.03 for male <1.29 for female)	116 (35.6)	71 (39.9)	45 (30.4)
	Not low (≥1.03 for male ≥1.29 for female)	210 (64.4)	107 (60.1)	103 (69.6)
LDL cholesterol (mmol/L)	Optimal (<2.6)	5 (1.5)	0 (0.0)	5 (3.4)
	Near optimal (2.6 to <3.4)	164 (50.3)	84 (47.2)	80 (54.1)
	Borderline high (3.4 to <4.1)	157 (48.2)	94 (52.8)	63 (42.6)
Triglycerides (mmol/L)	Normal (<1.7)	36 (11.0)	31 (17.4)	5 (3.4)
	Borderline high (1.7 to <2.3)	60 (18.4)	30 (16.9)	30 (20.3)
	High (2.3 to <5.6)	230 (70.6)	117 (65.7)	113 (76.4)

Table 4. Comparison of continuous measurements between females and males (N = 326). Values are presented as median (interquartile range); p-values are from Mann–Whitney U tests, with Holm adjustment.

Measure	Female n=178	Male n=148	U	p	Holm p
Age (years)	61.80 (56.83–63.68)	61.35 (56.95–63.80)	13137.0	0.968	1.000
BMI (kg/m²)	28.85 (21.42–35.27)	32.65 (27.88–36.02)	10074.0	<0.001	0.002
HbA1c (%)	9.60 (7.20–11.30)	9.05 (7.80–10.70)	13482.0	0.715	1.000
FBS (mmol/L)	6.50 (5.80–10.45)	7.20 (6.00–8.50)	13199.5	0.975	1.000
HDL-C (mmol/L)	1.37 (1.02–1.52)	1.31 (0.95–1.50)	14337.5	0.169	0.676
LDL-C (mmol/L)	3.44 (3.02–3.66)	3.29 (2.92–3.65)	14695.5	0.072	0.361
TG (mmol/L)	2.45 (1.98–2.67)	2.61 (2.33–2.65)	11212.0	0.021	0.124

3.4 Dietary associations with obesity

Obesity was observed in 147 of 220 participants (66.8%) reporting non-strict dietary adherence and 30 of 106 participants (28.3%) reporting strict adherence. Non-strict adherence was associated with higher odds of obesity relative to strict adherence (crude OR 5.10, 95% CI 3.07–8.47; Pearson $\chi^2 = 42.76$, df = 1; $p < 0.001$) (Table 5). The analysis was unadjusted and did not account for potential confounding factors.

The higher prevalence of obesity among non-strict adherers indicates a strong association in this dataset. However, this cross-sectional association does not establish that non-adherence caused obesity or that strict adherence reduced body weight. Self-reported adherence may be affected by recall bias, social desirability, and differences in understanding dietary recommendations. Total energy intake, physical activity, medication use, previous counselling, and other clinical characteristics may contribute to the observed relationship. The American Diabetes Association Standards of Care—2026 emphasize individualized nutrition therapy, sustained behavioral support, and comprehensive weight management [2,8].

In contrast, consumption of carbohydrate-rich meals was not significantly associated with obesity (55.1% versus 52.9%; OR 1.09, 95% CI 0.70–1.72; p = 0.696). This finding suggests that the reported consumption of carbohydrate-rich meals, as measured in this study, did not distinguish participants with obesity from those without obesity. However, the absence of a statistically significant association should not be interpreted as evidence that carbohydrate intake is unrelated to body weight. Carbohydrate quality, portion size, total energy intake, fiber content, and overall dietary patterns are important considerations in nutritional management [3,4]. The study's binary classification of carbohydrate-rich meals did not capture these dietary characteristics, potentially limiting its ability to identify meaningful nutritional associations.

Overall, these findings highlight the complexity of relationships between reported dietary behaviors and obesity among adults with T2DM. The cross-sectional design, reliance on self-reported dietary information, and use of unadjusted odds ratios limit causal interpretation. Future longitudinal studies incorporating validated dietary assessment instruments, quantitative nutrient intake, medication history, and relevant confounding variables are warranted to clarify these relationships and inform individualized nutritional interventions.

3.5 Dietary associations with lipid abnormalities

The present study identified significant associations between self-reported carbohydrate-rich meal consumption and adverse lipid indicators among adults with T2DM. Participants reporting carbohydrate-rich meals had higher odds of low HDL cholesterol (OR 4.11, 95% CI 2.39–7.09; $p < 0.001$) and LDL cholesterol ≥3.4 mmol/L (OR 2.03, 95% CI 1.28–3.22; p = 0.002). Furthermore, triglyceride concentrations ≥1.7 mmol/L were observed in 204 of 205 participants reporting carbohydrate-rich meals compared with 86 of 121 participants reporting other meal patterns, resulting in a markedly elevated odds ratio (OR 83.02, 95% CI 11.19–615.74; $p < 0.001$). These findings suggest a strong association between reported carbohydrate-rich meal consumption and lipid abnormalities in this hospital-based population. However, the extremely wide

confidence interval for triglycerides indicates considerable statistical uncertainty, primarily reflecting the near-complete occurrence of elevated triglycerides among participants reporting carbohydrate-rich meals.

Evidence from dietary intervention studies provides relevant context for interpreting these findings. Goldenberg et al. [14], in a systematic review and meta-analysis of randomized clinical trials, reported that low-carbohydrate and very-low-carbohydrate dietary interventions improved selected glycemic and metabolic outcomes among adults with T2DM at six months, although the sustainability of benefits at longer follow-up remained uncertain. Similarly, contemporary diabetes nutrition recommendations emphasize individualized carbohydrate intake, dietary quality, fiber-rich foods, and appropriate energy balance rather than a universally prescribed carbohydrate restriction [2,3]. Nevertheless, the present study classified carbohydrate-rich meals according to self-reported dietary patterns without quantifying carbohydrate intake, portion sizes, refined carbohydrate consumption, added sugars, or total energy intake. Consequently, the observed associations cannot establish whether carbohydrate quantity, carbohydrate quality, or other dietary and clinical factors contributed to the lipid abnormalities. The umbrella review by Szczerba et al. found benefits of some dietary interventions for metabolic indicators, while the certainty and size of effects differed across outcomes [5]. This broader evidence reinforces the need to distinguish reported meal composition from a prescribed and monitored dietary intervention.

Low HDL cholesterol was observed in 106 of 220 non-strict adherers (48.2%) and 10 of 106 strict adherers (9.4%; OR 8.93, 95% CI 4.42–18.03; Pearson $\chi^2 = 46.86$; $p < 0.001$). LDL cholesterol ≥3.4 mmol/L occurred in 132 non-strict adherers (60.0%) and 25 strict adherers (23.6%; OR 4.86, 95% CI 2.88–8.20; Pearson $\chi^2 = 37.99$; $p < 0.001$). Triglyceride concentrations ≥1.7 mmol/L occurred in 215 non-strict adherers (97.7%) and 75 strict adherers (70.8%; OR 17.77, 95% CI 6.67–47.38; Pearson $\chi^2 = 52.98$; $p < 0.001$) (Table 5).

The higher proportions of lipid abnormalities among non-strict adherers indicate strong associations in this dataset, but they do not establish causality. The wide confidence intervals, particularly for the triglyceride association, indicate uncertainty in the magnitude of these relationships. Lipid-lowering medication use, diabetes duration, disease severity, and dietary reporting accuracy may contribute to the observed patterns. Current diabetes care recommendations emphasize comprehensive cardiovascular risk assessment and individualized lipid management alongside nutritional interventions [11]. These findings warrant further investigation using validated dietary measures and adjustment for relevant confounders.

Overall, the associations between reported dietary practices and lipid abnormalities highlight the importance of assessing dietary quality and cardiometabolic risk together. However, the cross-sectional design, unadjusted odds ratios, subjective dietary classifications, and potential confounding prevent causal interpretation. Future prospective studies using validated dietary assessment methods, quantitative carbohydrate measurements, medication information, and multivariable statistical adjustment are needed to clarify these relationships and guide evidence-based nutritional interventions among adults with T2DM in Saudi Arabia.

Table 5. Dietary associations with obesity and lipid abnormalities (N = 326)

Comparison	Outcome	First group n (%)	Reference n (%)	OR (95% CI)	χ^2	p
Non-strict vs strict dietary adherence	Obesity	147 (66.8)	30 (28.3)	5.10 (3.07–8.47)	42.76	<0.001
Carbohydrate-rich vs other meals	Obesity	113 (55.1)	64 (52.9)	1.09 (0.70–1.72)	0.15	0.696
Non-strict vs strict dietary adherence	Low HDL-C	106 (48.2)	10 (9.4)	8.93 (4.42–18.03)	46.86	<0.001
Non-strict vs strict dietary adherence	LDL-C ≥3.4 mmol/L	132 (60.0)	25 (23.6)	4.86 (2.88–8.20)	37.99	<0.001
Non-strict vs strict dietary adherence	TG ≥1.7 mmol/L	215 (97.7)	75 (70.8)	17.77 (6.67–47.38)	52.98	<0.001

Comparison	Outcome	First group n (%)	Reference n (%)	OR (95% CI)	χ^2	p
Carbohydrate-rich vs other meals	Low HDL-C	95 (46.3)	21 (17.4)	4.11 (2.39–7.09)	27.89	<0.001
Carbohydrate-rich vs other meals	LDL-C ≥3.4 mmol/L	112 (54.6)	45 (37.2)	2.03 (1.28–3.22)	9.27	0.002
Carbohydrate-rich vs other meals	TG ≥1.7 mmol/L	204 (99.5)	86 (71.1)	83.02 (11.19–615.74)	62.64	<0.001

All p-values in this table use Pearson's chi-square test without continuity correction (df = 1); all expected cell frequencies exceed five. Odds ratios are unadjusted, with log-Wald 95% confidence intervals. Adherence groups: non-strict n = 220 and strict n = 106. Carbohydrate meal groups: carbohydrate-rich n = 205 and other meals n = 121. Percentages are within each exposure group. Obesity was defined as BMI ≥30 kg/m².

3.6 Clinical implications and future research

The most useful clinical implication is the need to assess dietary quality and barriers to sustained self-management alongside weight, glycemic status, and lipids. Practical evaluation could address portions, refined versus whole-grain foods, fiber sources, meal skipping, and the feasibility of dietary recommendations. Such assessment is consistent with individualized nutrition therapy and current behavioral guidance [2,3]. This study did not evaluate an intervention and cannot demonstrate that any specific counselling strategy improves outcomes. The DSMES consensus report recommends coordinated educational and nutritional support and attention to barriers that affect participation in care [7].

Future studies should use validated dietary instruments, distinguish food quality from carbohydrate quantity, and obtain clinical measurements close to the dietary assessment. Repeated observations would help distinguish adoption of dietary changes after adverse findings from the possible effects of diet on subsequent outcomes. Larger samples with covariate information would permit adjusted analyses and more stable estimation of sparse-cell associations. Physical activity associations require verified participant-level records rather than inference from overall frequencies.

3.7 Strengths and limitations

This study provides locally relevant information on dietary practices and cardiometabolic indicators among adults with type 2 diabetes in Al-Ahsa. Dietary questionnaires and clinical measurements were obtained during the same study period, with clinical measurements recorded on or close to questionnaire completion. Nevertheless, the single-center purposive sample limits generalizability. Self-reported dietary practices and anthropometric measurements may be affected by recall and reporting bias. The lack of quantitative dietary intake, medication history, and adjustment for potential confounders, together with sparse cells in selected analyses, limits the interpretation and precision of the observed associations. The cross-sectional design precludes causal inference.

4. CONCLUSION

Obesity, elevated HbA1c, and lipid abnormalities were common in this hospital-based sample of adults with T2DM; 67.5% reported non-strict dietary adherence. Non-strict adherence was associated with higher odds of obesity, low HDL cholesterol, LDL cholesterol ≥3.4 mmol/L, and triglycerides ≥1.7 mmol/L. Carbohydrate-rich meal consumption was associated with lipid abnormalities but not obesity. These unadjusted cross-sectional findings support further study using validated dietary assessments and relevant confounders; they do not establish causal effects.

ACKNOWLEDGEMENTS

The authors are thankful to the Clinical Nutrition Department, College of Applied Medical Sciences, King Saud Bin Abdulaziz University for Health Sciences, Al Ahsa, Saudi Arabia, for academic support.

FUNDING

The authors received no financial support for the research, authorship, and/or publication of this article.

AUTHOR CONTRIBUTIONS

All authors contributed in Conceptualization, methodology, literature synthesis, writing – original draft, writing – review and editing, and final approval of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ETHICS STATEMENT

Ethical approval was obtained from the King Abdullah International Medical Research Center (KAIMRC)(NRA23A/029/07) Institutional Review Board (IRB/1990/23).

Electronic informed consent was obtained from all participants.

DATA AVAILABILITY STATEMENT

Data were anonymized and stored securely with restricted access.

CLINICAL TRIAL REGISTRATION

Not applicable.

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