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The association between different types of dietary fat intake and blood lipids in Type 2 diabetes patients: sex differences

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Abstract

Purpose – Blood lipid and lipoprotein abnormalities are common among patients with diabetes. The study aimed to assess dietary fat intake and its association with blood lipids among patients with Type 2 diabetes mellitus (T2DM) considering sex differences.

Design/methodology/approach – A cross-sectional observational study was conducted with patients (207 males and 197 females) with T2DM. The daily food intake and its contents of fat and fat types were assessed through face-to-face interview. Anthropometric measurements, glycated hemoglobin (HbA1c), triglyceride, total cholesterol (TC), high-density lipoprotein (HDL) cholesterol and low-density lipoprotein (LDL) cholesterol were initially recorded.

Findings – The results revealed that TC, LDL and HDL cholesterol levels were significantly higher in females than in males. However, the TC: HDL ratio was significantly higher in males than in females. The results also showed that the daily intake of saturated fatty acid (SFA) slightly exceeded the daily recommended allowance. However, the monounsaturated fatty acid + polyunsaturated fatty acid/SFA (MUFA + PUFA/SFA) ratio was within the recommended ratio. In addition, this study found that the main sources of SFA and cholesterol intake were milk and milk products. A significant association between high fat intake and HbA1c levels was observed ($r = 0.234, p < 0.001$).

Research limitations/implications – As it is a cross-sectional observational study, this study has the natural limitation where it can only demonstrate an association.

Originality/value – The types of dietary fat intake may contribute to blood lipid abnormalities and differences effects may exist among male and female. Studies on the effect of daily fat intake and its types on blood lipids in patients with diabetes, in particular Saudi patients with diabetes are limited. This study focused on the amount and type of the consumed fat among male and female Saudi patients with T2DM and studied the relationship between the type of consumed fat and blood lipid profiles.

Keywords Cholesterol, Diabetes mellitus, HDL cholesterol, LDL cholesterol, Lipids, Saturated fatty acid

Paper type Research paper

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Introduction

The global prevalence of diabetes mellitus (DM) is expected to rise from 9.3% in 2019 to 10.9% in 2045 (Saeedi *et al.*, 2019). It is documented that Type 2 diabetes mellitus (T2DM) is the most common type of DM. There are many factors that are involved in influencing the prevalence of DM, such as age, sex, genetic susceptibility, socioeconomic status and lifestyle. However, the strongest risk factors for developing diabetes are habitual eating patterns, obesity and a sedentary lifestyle (Davies *et al.*, 2022; Jaacks, Siegel, Gujral, & Narayan, 2016).

Abnormalities in blood lipoprotein and lipid levels are common among T2DM patients. A high prevalence of dyslipidemia is found among patients with T2DM (Alzaheb & Altemani, 2020). DM significantly lowers high-density lipoprotein (HDL cholesterol) and elevates low-density lipoprotein (LDL cholesterol) and triglyceride (TG) levels (Vergès, 2015). It is evident that these dyslipidemic features are associated with an increased risk of cardiovascular disease. Patients with T2DM have a high risk of death from cardiovascular disease. This would expose individuals who are at risk of diabetes complications such as heart disease-associated mortality (Huxley, Barzi, & Woodward, 2006). The mortality rate of diabetes associated with cardiovascular diseases varies among ethnicity and sex groups. In terms of ethnicity, it has been found that non-Hispanic White had a higher risk of cardiovascular disease than African Americans, Asians and Hispanics (Fan, 2017). In addition, female patients with diabetes were at greater risk for fatal coronary heart disease in comparison with males. For most of patients with diabetes, dietary intervention and physical activities can improve diabetic dyslipidemia (Krauss, 2004).

Dietary fat is an essential part of daily macronutrient intake. It is recommended that approximately 20–35% of the total dietary energy intake should come from fat intake (FAO, 2010). However, the type of fat consumed is more critical than the total amount. Therefore, most dietary recommendations aim to reduce saturated fatty acid (SFA) intake to less than 10% of energy, monounsaturated fatty acid (MUFA) intake to over 10%, and polyunsaturated fatty acid (PUFA) intake to less than 10% of energy intake (Acosta-Montaño & García-González, 2018). A diet rich in SFA has been considered a trigger of T2DM and patients with T2DM are at high risk of death from cardiovascular (FAO, 2010; Raghavan *et al.*, 2019). There is a strong positive correlation between the intake of saturated and trans-fats and coronary heart diseases. It has been found that the adherence score to the Saudi dietary guidelines regarding fruit and olive oil was significantly lower among patients with cardiovascular disease (CVD) compared to non-CVD patients (Alkhaldy *et al.*, 2019). Trans-fats can also destroy HDL cholesterols (Hu & Willett, 2002). On the other hand, dietary MUFA and PUFA may contribute to reduced diabetes risk (Rice Bradley, 2018). However, it is still inconclusive whether PUFA intake has a beneficial effect on glycemic control in diabetes (Telle-Hansen, Holven, & Ulven, 2018).

Assessing the types of dietary fat intake among patients with T2DM may be useful to understand the association between the types and the sources of consumed fat and blood lipid profiles in male and female patients with diabetes. We hypothesized that there would be differences in the dietary fat intakes among male and female patients with T2DM and fat types that may contribute to blood lipid abnormalities. As such, this study aimed to assess the dietary fat intake and examine its association with blood lipids among patients with T2DM, considering sex differences.

Materials and methods

Patients

In this cross-sectional study, a total of 404 patients (207 males and 197 females) with T2DM were recruited from the diabetes clinic at National Guard Health Affairs, Al-Ahsa, Saudi

Arabia. Using convenience sampling, the researchers screened all patients with T2DM who attended the diabetes clinic between November 2018 and March 2019 for enrollment.

Inclusion and exclusion criteria

The inclusion criterion was patients with T2DM who were taking oral or injection medications and aged between 20 and 80 years. The exclusion criteria were the presence of chronic kidney diseases, coronary heart diseases, or liver diseases and the use of medications that affect diabetes control, e.g. glucocorticoids and pregnancy-related medications.

Ethical considerations

The study was approved by the Institutional Review Board (IRB), Ministry of National Guard Health Affairs (Ref. No. IRBC/0666/19). An informed written consent was obtained from each patient involved in the study which was conducted according to the guidelines of the Declaration of Helsinki.

Biographical measurements

Blood pressure, height, and weight were initially recorded upon arrival at the clinic. Then, the researchers reviewed the patient's electronic medical records that were available at the time of the interview and collected data for the following variables: body mass index (BMI), fasting blood glucose (FBG), random blood glucose (RBG), glycated hemoglobin (HbA1c), triglyceride (TG), total cholesterol (TC), HDL and LDL levels. The BMI was estimated from weight in kilograms divided by the height in meters square. The five main BMI categories are underweight (<18.5 kg/m^2), normal weight (25 kg/m^2 > BMI $\geq$18.5 kg/m^2), overweight (30 kg/m^2 > BMI $\geq$25 kg/m^2), obese (40 kg/m^2 > BMI $\geq$30 kg/m^2) and severely obese (BMI $\geq$40 kg/m^2) (WHO Expert Consultation, 2004).

Normal levels of FBG, RBG and HbA1c are $<$5.6 mmol/l, $<$11 mmol/l and 5.6%, respectively. Normal levels of TG, TC, HDL and LDL cholesterol are $\leq$1.7 mmol/l, $\leq$5.18 mmol/l, $\geq$1.55 mmol/l and $\leq$2.6 mmol/l, respectively (ADA, 2018; IDF, 2017).

Dietary assessment

A validated questionnaire (Al-Mssallem, 2018; Al-Mssallem, Elmulthum, & Elzaki, 2019) was applied to collect data on the dietary food intake from patients through face-to-face interviews. A four-point scale (daily, weekly, monthly and never) was used for reporting the frequency and the amount of the food intake. The daily intakes of energy, carbohydrates, fat, protein and non-starch polysaccharides were estimated by using the food composition tables. In addition, total cholesterol (TC), saturated fat, mono- and polyunsaturated fat contents of each food intake were determined from the food composition tables (Musaiger, 2011; USDA, 2016).

Statistical analysis

Collected data were entered and cleaned in a secured Excel data sheet and exported to Statistical Package for Social Sciences (SPSS software, version 26, IBM Corp.© Copyright IBM Corporation) for analysis. Descriptive statistics were reported by calculating the means and standard deviations for biographical measures, the daily intake of different foods, total energy and macronutrient intake, to find the differences between male and female patients, along with the percentages of continuous variables of major nutrients for every food item. Student's *t*-test with a two-tailed significance level of less than 5% ($p < 0.05$) was used to compare biographical measures, the daily intake of different foods, total energy and macronutrient intake between male and female patients. The correlations between saturated fat intake and HbA_{1c} level, HDL and LDL cholesterol levels, monounsaturated fat and polyunsaturated fat percentages, among male and female patients were assessed using the Pearson correlation test.

Results

Characteristics of patients

Four hundred and four patients with T2DM were included in this study. They were divided into groups of males ($n = 207$) and females ($n = 197$). The anthropometric measurements and laboratory analysis of the study population are presented in Table 1. There was a significant difference between the two groups in terms of BMI, total blood cholesterol, LDL and HDL levels, which were significantly higher in females than in males ($p < 0.05$). However, the diastolic blood pressure (DBP) was significantly higher in males than in females ($p < 0.01$).

Additionally, the total cholesterol to HDL-cholesterol ratio (TC:HDL ratio) was significantly ($p < 0.01$) higher in males, with a value of 4.62, compared to that of 4.13 in females (Table 1). The association between TC and HDL and LDL is presented in Figure 1.

Dietary assessment

The daily consumption of food among male and female patients with T2DM is shown in Table 2. The results showed significantly high consumption of meat, eggs, and milk and milk products among male patients. Moreover, male patients consumed more legumes, fruits and vegetables than females ($p < 0.001$). However, female patients had higher consumption of fast food than males ($p < 0.001$).

Daily intake of macronutrients

Table 3 demonstrates the differences in macronutrient intake among male and female patients with T2DM. The total calorie, fat, protein and carbohydrate intakes were significantly higher in males than in females ($p < 0.01$). Male patients also had a significantly higher intake of saturated fat, cholesterol and non-starch polysaccharide (NSP) than females ($p < 0.01$).

	Males (207)		Females (197)		
Measurements	Mean	SE	Mean	SE	*P*
Age (years)	54.86	0.73	55.72	0.62	0.370
Height (m)	167.26	0.48	153.90	0.38	<0.01
Weight (kg)	90.82	1.16	83.68	1.13	<0.01
DBP (mm Hg)	74.53	0.74	70.49	0.72	<0.01
SBP (mmHg)	139.22	1.27	138.10	1.31	0.538
BMI (kg/m^2)	32.45	0.40	35.23	0.43	<0.01
HbA1c (%)	8.24	0.11	8.25	0.11	0.942
FBG (mmol/L)	9.85	0.26	9.64	0.26	0.565
RBG (mmol/L)	11.59	0.30	10.83	0.30	0.078
HDL (mmol/L)	0.95	0.01	1.15	0.02	<0.01
LDL (mmol/L)	2.62	0.06	2.79	0.06	<0.05
TC (mmol/L)	4.25	0.06	4.58	0.06	<0.01
TC:HDL ratio	4.62	0.08	4.13	0.07	<0.01
TG (mmol/L)	1.69	0.06	1.65	0.07	0.677

Note(s): DBP, diastolic blood pressure; SBP, systolic blood pressure; BMI, body mass index; HbA1c, glycated hemoglobin; FBG, fasting blood glucose; RBG, random blood glucose; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TC, total cholesterol; TG, triglycerides
Source(s): Table by the authors

Table 1. Biographical measurements of male ($n = 207$) and female ($n = 197$) patients with T2DM

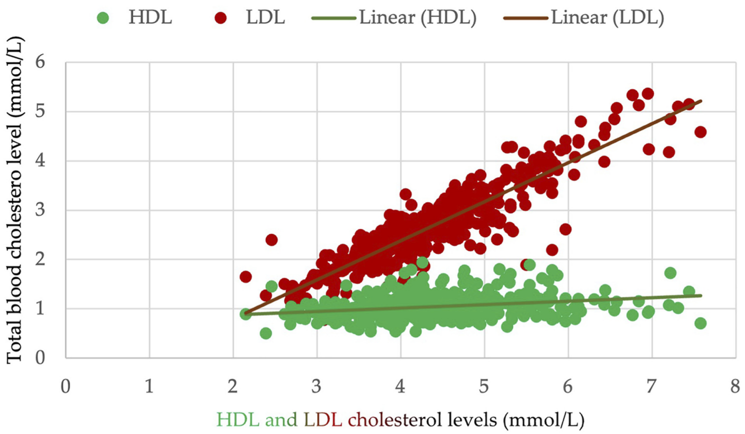

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Figure 1. Correlation among total blood cholesterol level, HDL and LDL cholesterol levels

Table 2. The daily intake of different foods among male and female patients with Type 2 diabetes (n = 404)

Food item (serving/day)	Males (207) Mean	SE	Females (197) Mean	SE	p
Fruits and vegetables	4.67	0.16	3.45	0.13	<0.001
All drinks	0.66	0.06	0.68	0.08	0.810
Milk and milk products	1.77	0.06	1.35	0.06	<0.001
Meat	0.28	0.02	0.22	0.01	0.007
Chicken	0.57	0.02	0.59	0.03	0.580
Fish	0.12	0.01	0.11	0.01	0.187
Eggs	0.33	0.02	0.24	0.02	0.004
Rice (Kabsa)	9.84	0.25	9.44	0.27	0.277
Pasta	0.80	0.06	0.89	0.07	0.278
White and brown bread	4.69	0.10	4.43	0.12	0.105
legumes served with fat	0.93	0.08	0.48	0.04	<0.001
Fast foods	0.10	0.01	0.19	0.03	0.001
Confectionaries	0.38	0.06	0.50	0.06	0.137

Source(s): Table by the authors

However, when these figures were accounted for as a percentage of energy intake, males had a significantly ($p < 0.05$) lower fat percentage, with a value of 24% compared to that of 25% for females (Figure 2). The percentages of SFA, MUFA and PUFA in total energy and total fat intakes are presented in Figures 2 and 3, respectively, for both males and females. The dietary intake of SFA reached 7.6% and 7.5% of the total energy for males and females, respectively (Figure 2). When it was expressed as a percentage of total fat intake, it was also obvious that the percentage of SFA was higher in males, with a value of 31%, compared to that of 29% in females ($p < 0.01$). In contrast, females had a higher percentage of PUFA (30%) than in males, who had with a value of 29% ($p < 0.05$). The percentage of MUFA was similar for both males and females (Figure 3). In contrast, the MUFA + PUFA/SFA ratio was significantly higher in females than in males, with values of 1.95 and 1.77, respectively ($p < 0.01$).

Additionally, a weak connection ($r = 0.234$, $p < 0.001$) was observed between the total fat intake and HbA1c level (Figure 4(a)), whereas there was a strong relationship ($r = 0.95$, $p < 0.001$) between fat intake and SFA intake (Figure 4(b)).

Table 3. Total calorie and macronutrient intake among male and female patients with T2DM (n = 404)

Total intake	Males (207) Mean	SE	Females (197) Mean	SE	p
Total fat (g/day)	59.30	1.11	55.00	1.19	0.009
Total SFA (g/day)	18.59	0.42	16.48	0.44	0.001
Total MUFA (g/day)	14.12	0.25	13.20	0.27	0.014
Total PUFA (g/day)	17.07	0.34	16.77	0.39	0.566
MUFA/SFA ratio	0.79	0.01	0.84	0.01	0.009
PUFA/SFA ratio	0.98	0.02	1.10	0.03	0.002
MUFA + PUFA/SFA ratio	1.77	0.03	1.95	0.04	0.002
Total cholesterol (mg/day)	168.43	5.14	138.20	4.62	<0.001
Total protein (g/day)	75.46	1.58	63.89	1.26	<0.001
Total CHO (g/day)	340.75	5.06	307.92	5.26	<0.001
Available CHO (g/day)	308.21	4.65	282.70	4.97	<0.001
NSPs (g/day)	32.53	0.78	25.21	0.61	<0.001
Total energy (cal/day)	2172.80	33.56	1957.59	34.10	<0.001

Note(s): SFA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; CHO, carbohydrates; NSPs, non-starch polysaccharides
Source(s): Table by the authors

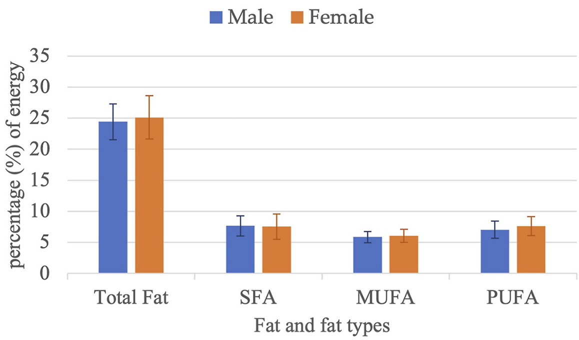

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Figure 2. The percentage of fats, SFA, MUFA and PUFA in total energy intake among male (n = 207) and female (n = 197) patients with T2DM

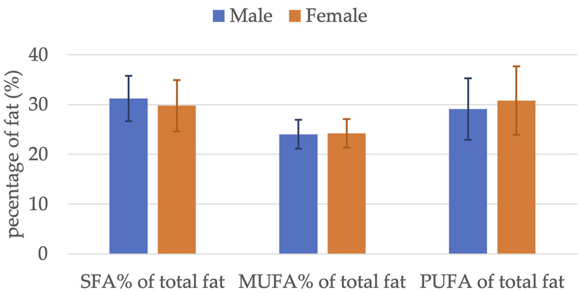

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Figure 3. The percentage of SFA, MUFA and PUFA in total fat intake among male (n = 207) and female (n = 197) patients with T2DM

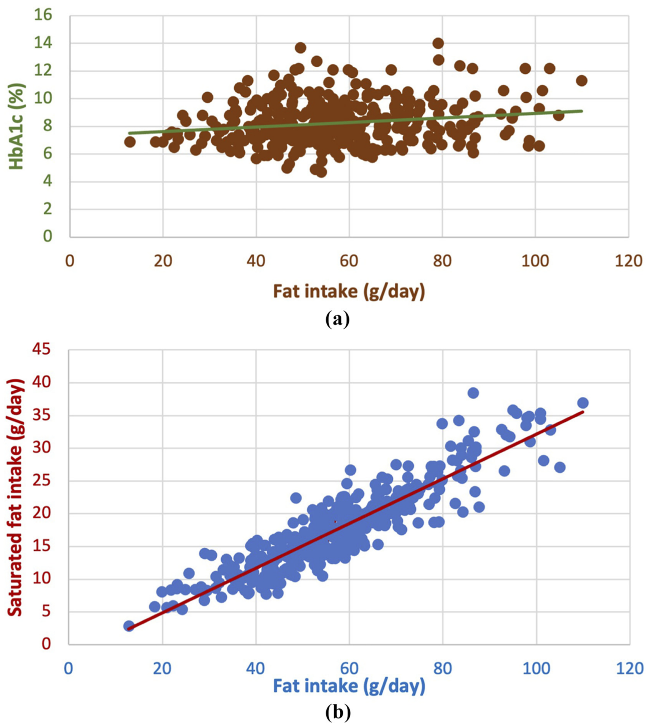

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Figure 4. The association of fat intake (g/day) with the HbA_{1c} level (a) and saturated fat intake (b) among patients with Type 2 diabetes

Furthermore, Figure 5 showed that SFA% intake was negatively associated with both PUFA intake ($r = -0.744$; $p = 0.000$) and MUFA intake ($r = -0.213$; $p = 0.000$).

Dietary assessment

Figure 6 reveals that the highest percentage of PUFA comes from cooked rice (67%). However, milk and milk products were considered a main source of cholesterol (28%), followed by eggs (25%) and chicken (22%). Milk and milk products were also the main sources of SFA which a percentage of 34%.

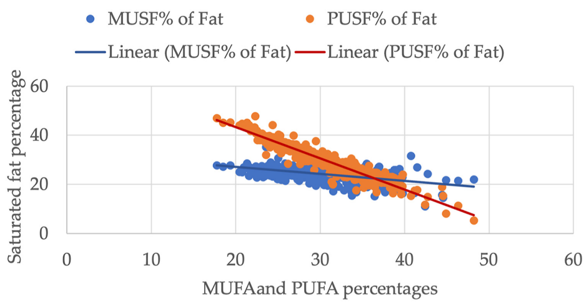

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Figure 5. The percentage of SFA was negatively associated with the percentage of PUFA and MUFA intakes

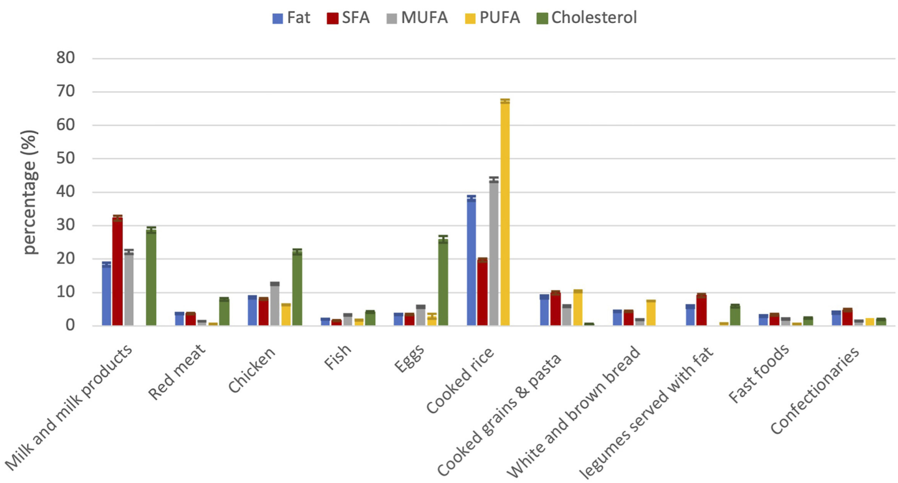

Figure 6.
The source of daily intake of total fat and types of fat from different foods among patients with Type 2 diabetes (n = 404)

Source(s): Figure by the authors

Discussion

The present study investigated dietary fat intake among male and female patients with T2DM. Our findings revealed that females have significantly higher BMI, TC and LDL cholesterol levels than males. Indeed, obesity is more frequently diagnosed in diabetic females than males, which could be explained because females perform less physical activity than males (Kautzky-Willer *et al.*, 2019; McCollum, Hansen, Lu, & Sullivan, 2005; Summers *et al.*, 2002). However, the TC:HDL ratio was significantly higher in males than in females. The ratio of TC to HDL is regarded as a more specific marker of diabetes complications than LDL cholesterol, and this ratio is an uncomplicated approach to getting an idea of whether a person's TC levels are in the healthy range. In this study, the TC:HDL ratio was slightly higher than 4, which is considered a sign of unhealthy cholesterol levels for both males and females. A healthy balance of the TC, HDL cholesterol and LDL cholesterol is necessary among patients with diabetes to prevent diabetes complications such as heart diseases, and a TC:HDL ratio above 6 is regarded as a factor of high risk of heart diseases (Jiao *et al.*, 2019; Mensink, Zock, Kester, & Katan, 2003). Some suggest that each 10% increase in HDL cholesterol variability reduces the risk of cardiovascular mortality by 31% (Wang *et al.*, 2021).

It is known that there was an obvious trend toward lower intakes of whole grains, fruits and vegetables among our study's participants in which the consumption of fruits and vegetables was below the recommended daily allowance. In comparison, fruit and vegetable consumption was significantly lower for females than for males. The current guidelines for people with diabetes recommend 8–10 servings of fruits and vegetables every day (ADA, 2017). It has been found that a vegetarian diet leads to controlled diabetes (Yokoyama, Barnard, Levin, & Watanabe, 2014).

Likewise, a lower intake of NSPs was observed among females than males. A large body of evidence has reported that the increased consumption of NSPs has a positive effect on diabetes patients (McRae, 2018).

In this study, the dietary intake of SFA was slightly higher than the daily recommended allowance, which were 7.6% and 7.5% of the total energy for both males and females, respectively. The current average intake of SFA among Americans is 11% of the total energy intake. The American Heart Association (AHA) recommends that less than 7% of the total energy intake comes from SFA and that cholesterol intake should be less than 300 mg per day (USDA, 2020). Moreover, this study found that the TC intake was within the daily recommended allowance for both males and females.

When the SFA intake was expressed as a percentage of total fat intake, it exceeded the daily recommended allowances for both groups, which were 31% and 29% for males and females, respectively. It is recommended that the SFA intake should be less than 20% of the total fat intake (FAO, 2010). Consequently, the MUFA and PUFA intakes were below the daily recommended allowance for both groups. Reducing SFA intake is considered a primary tool for lowering LDL cholesterol levels. The replacement of SFA by MUFA can lower LDL cholesterol, but PUFA can lower both LDL and HDL cholesterol (Siri-Tarino, Sun, Hu, & Krauss, 2010). Evidence has shown that a Mediterranean diet, which is rich in MUFA, can improve glycemic control and blood lipids (Qian, Korat, Malik, & Hu, 2016). On the other hand, the substitution of a diet rich in SFA with a diet rich in PUFA can contribute to decreasing diabetes complications, improving insulin sensitivity and reducing the risk of developing T2DM (Jiao *et al.*, 2019; Lovejoy *et al.*, 2002; Summers *et al.*, 2002). Moreover, a prospective study revealed that PUFA intake was associated with a reduced risk of developing T2DM (Salmerón *et al.*, 2001). In addition, a recent meta-analysis of cohort studies has suggested that trans-fat intake can increase the risk of T2DM, but PUFA intake can reduce the risk. It has been estimated that substituting 2% of trans-fat energy energetically with PUFA would lead to a lower risk of developing T2DM by approximately 40% (Hu, Fang, Zhang, & Chen, 2022; Salmerón *et al.*, 2001). In terms of MUFA + PUFA/SFA ratio, it has been found that higher MUFA + PUFA/SFA ratio has resulted in greater accumulation of liver cholesterol (Chang & Huang, 1998). For maintaining good health, it is recommended keeping the proportion of SFA, MUFA and PUFA within the ratio of 1:1.5:1 (Grover *et al.*, 2021). In addition, the ratio of MUFA + PUFA/SFA was suggested to be below 3 (Chang & Huang, 1998). Indeed, the MUFA + PUFA/SFA ratio should not exceed 2 for maintaining low levels of plasma and liver cholesterol (Chang & Huang, 1999). In this study, the MUFA + PUFA/SFA ratio was within the recommended ratio, which did not exceed 2 for either males or females.

In this study, the main sources of SFA were milk and milk products, which are also the main source of dietary cholesterol intake. In Saudi Arabia, an exploratory study was conducted, to identify common dietary patterns and examine their associations with eating behaviors among patients with T2DM, it was found that the dairy products were positively correlated with a higher cholesterol (Aljahdali & Bawazeer, 2022). In the US diet, sandwiches including burgers and tacos were the main sources of SFA. There is a shift in the structure of the diet toward animal sources and lower intakes of whole grains, fruits and vegetables (USDA, 2020). In addition, the study found that the adherence score to the Saudi dietary guidelines regarding the consumption of whole grains, fruit and olive oil was poor among patients with CVD compared to non-CVD patients (Alkhaldy *et al.*, 2019). The substitution of foods rich in SFA from fat-rich dairy products and meats with foods rich in short-chain PUFA, including vegetable oils, is recommended for improving insulin sensitivity (Risérus, Willett, & Hu, 2009). Even though dairy fat contains 65% SFA, it has been observed that dairy fat could contribute to a decreased risk of T2DM. A possible explanation could be related to the types of fatty acids in milk fat, including short-chain fatty acids (Ericson *et al.*, 2015).

This study found a strong correlation between total fat intake and dietary SFA intake, whereas there was a weak significant correlation between total fat intake and HbA1c level. It has been found that SFA intake was correlated with elevated TC and LDL cholesterol (Ruiz-Núñez, Dijck-Brouwer, & Muskiet, 2016). It is believed that a high intake of SFA can lead to dyslipidemia in diabetes patients (Guasch-Ferré *et al.*, 2017). Moreover, a reduction in SFA can help maintain TC, LDL cholesterol and HDL cholesterol levels among patients with diabetes (Hooper, Martin, Abdelhamid, & Davey Smith, 2015).

There are some limitations to this study. Clearly, this was an assessment of only dietary fat intake among patients with diabetes. However, the results provide useful information on the types of fat intake and their impact on blood lipid profile among both male and female patients with diabetes. It is unfortunate that this study can only demonstrate an association as it is a cross-sectional observational approach. Further study, particularly a clinical intervention trial, may be required to investigate the effect of specific types of dietary fat intake on blood triglycerides, TC, HDL cholesterol and LDL cholesterol among patients with diabetes.

Conclusion

In this study, there was a positive relationship between high fat intake and HbA1c levels among patients with T2DM. In addition, the daily intake of saturated fat was slightly higher than the daily recommended allowance and the milk and milk products were the major source of the saturated fat in both males and females. Modifications in habitual eating patterns, including the source and quality of dietary fat intake, are recommended.

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