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Prevalence of different patterns of dyslipidemia in patients with type 2 diabetes in an Iranian population

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Abstract

Background Diabetic dyslipidemia is a complex multidimensional abnormality. However, earlier studies did not focus on the prevalence of various patterns of dyslipidemia. We categorized dyslipidemia into three groups. Single dyslipidemia (7 patterns) and mixed dyslipidemia consisted of dual (16 patterns) and triple (4 patterns) combinations of different patterns of single dyslipidemia.

Methods This cross-sectional study included 2097 patients with type 2 diabetes (T2D) between 2014 and 2021. We measured blood lipid profile parameters and calculated the atherogenic index of plasma (AIP) using log (TG/HDL-C). We analyzed dyslipidemia as a categorical variable and expressed results as numbers and percentages. We used Chi-square or Fisher exact tests to compare categorical variables.

Results A total of 97.81% of patients had at least one lipid abnormality. High AIP (88.0%) was the most common pattern, followed by LDL-C ≥ 70mg/dl (80.1%), and low HDL-C (58.0%). 73.87% of patients had mixed dyslipidemia. The dual combination of high AIP and LDL-C ≥ 70mg/dl was the most common pattern of mixed dyslipidemia (71.1%). Additionally, 24.7% of patients had triple combination dyslipidemia. All dyslipidemia patterns were more common among women than men, except for high AIP. In patients with T2D and coronary artery disease (CAD) history, high AIP was the most prevalent pattern of dyslipidemia (87.5%), followed by LDL ≥ 70mg/dl (68.6%). Also, the dual combination of high AIP and LDL ≥ 70mg/dl was the most common pattern of mixed dyslipidemia in patients with T2D and CAD history (60.67%).

Conclusion This study showed that single and mixed (dual and triple combination) dyslipidemia is common among patients with T2D. High AIP and LDL-C ≥ 70mg/dl were the most common patterns, either single or combined, in patients with or without CAD.

Keywords Diabetes, Single dyslipidemia, Mixed dyslipidemia, Atherogenic index of plasma

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Introduction

The prevalence of diabetes, especially type 2, has risen dramatically in the past decades. This increase is due to obesity, poor lifestyle, unhealthy dietary habits, aging, and increased life expectancy. The international diabetes federation (IDF) estimated the global prevalence of diabetes at 8.8% (425million) in 2017 and at 10.5% (536.6million people) in 2021, rising to 12.2% (783.2million) in 2045[1, 2]. Diabetes caused 6.7million deaths in 2021, which means; one death every five seconds [3].

Cardiovascular diseases (CVD), including; coronary artery disease (CAD), myocardial infarction (MI), stroke, and congestive heart failure, are the primary causes of death in patients with T2D [4]. The focus on diabetic dyslipidemia, especially increased LDL-C, has been mostly on the risk of CVD. However, different patterns of dyslipidemia have been reported in various cancers, especially high TG and low HDL-C in colorectal, prostate, lung, breast, and endometrial cancers [5–9]. Also, dyslipidemia is associated with microvascular complications of diabetes, including retinopathy and nephropathy [10, 11].

Many studies determined the prevalence of dyslipidemia in the general population [12–18] and in patients with diabetes, focused on single dyslipidemia, especially high LDL-C. [19–29]. LDL-C was calculated using the Friedewald formula. Few studies reported the prevalence of mixed dyslipidemia in patients with diabetes, including dual and triple combinations of high TG, high LDL-C, or low HDL-C [19, 20, 25, 27, 28]. However, different patterns of diabetic dyslipidemia and their effects have not been studied well.

Diabetic dyslipidemia usually has been defined as high Triglyceride (TG), high low-density lipoprotein cholesterol (LDL-C), and low high-density lipoprotein cholesterol (HDL-C). However, less attention has been paid to the other dyslipidemia patterns. In the current study, we considered single dyslipidemia, including; high TG, high LDL-C, low HDL-C, high non-high-density lipoprotein cholesterol (non-HDL-C), high atherogenic index of plasma (AIP), and mixed dyslipidemia; which we defined as the dual and triple combinations of different patterns of single dyslipidemia.

Therefore, we conducted a study on 2097 patients with T2D in an Iranian population to determine the prevalence of different patterns of single or mixed dyslipidemia using lipid profile (TG, LDL-C, HDL-C, non-HDL-C, AIP).

Material and methods

Study design & data collection

We designed a cross-sectional study and evaluated patients with T2D referred to the diabetes clinic of Vali-E-Asr hospital affiliated with Tehran University of medical sciences between 2014 and 2021. We diagnosed diabetes with the American Diabetes Association (ADA) Criteria. We obtained the age and duration of diabetes using a questionnaire. Well-trained examiners conducted anthropometric measurements, including height, weight, and waist circumference. Using a stadiometer (rounded to the nearest 0.1cm), we measured height in the upright position. Using a calibrated balance beam scale, we measured weight in the upright position (rounded to the nearest 0.1kg). We calculated body mass index (BMI) by dividing weight (kg) by height squared (m2). We measured waist circumference at the middle point between the lower borders of the rib cage and the iliac crest (rounded to the nearest 0.1cm) [30]. Well-trained nurses measured blood pressure using a calibrated mercury sphygmomanometer. We measured fasting blood glucose (FBS), HbA1C, 2-hour postprandial blood glucose (2hpp), creatinine, and blood lipid profile, including TG, total cholesterol, LDL-C, and HDL-C. We calculated non-HDL-C by reducing HDL-C from total cholesterol and AIP using the log (TG/HDL-C) formula.

We included patients with at least one complete blood lipid profile (TG, total cholesterol, LDL-C, HDL-C) in this study. We calculated the mean values for patients with multiple blood lipid profile results. The patients mainly were homogenous, middle class, with middle to high school education levels. They had access to health care facilities and insurance. Also, approximately 95% of patients were taking Statins. Imam Khomeini hospital's institutional research ethics committee approved this study (Ethics code: IR.TUMS.IKHC.REC.1398.270), and we obtained informed consent from all patients.

Variable definitions

We divided dyslipidemia patterns based on NCEP ATP III (National Cholesterol Education Program-Adult Treatment Panel III) and AHA/ACC (The American Heart Association/The American College of Cardiology) guidelines into two main groups [31, 32]: (A) Single dyslipidemia and (B) mixed dyslipidemia. We defined *single dyslipidemia* as a disorder in a lipid profile component that included seven patterns: high TG (≥150 and ≥200), high LDL-C (≥70 and ≥100), low HDL-C (<40 in men and <50 in women), high non-HDL-C (≥130), and high AIP (>0.24) [33]. Patients with single dyslipidemia may have other patterns of dyslipidemia. *Mixed dyslipidemia* consisted of dual and triple combinations. We defined *dual combination dyslipidemia* as a concurrent disturbance in two and *triple combination dyslipidemia* as a concurrent disturbance in three different lipid profile parameters. Dual and triple combination dyslipidemia included 16 and 4 patterns, respectively (Fig.1).

Also, we investigated the prevalence of dyslipidemia in patients with T2D and a history of coronary artery disease (CAD). CAD was defined as stable angina, unstable

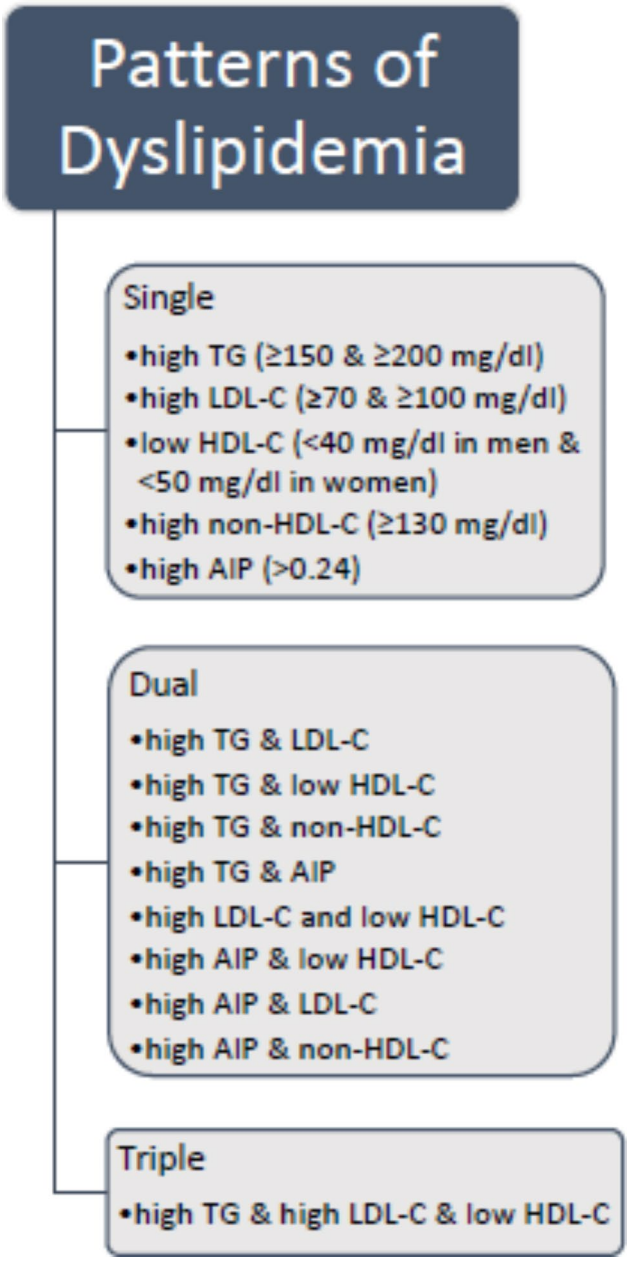

Fig. 1 Different patterns of dyslipidemia in the current study
TG: triglyceride; LDL: low-density lipoprotein; HDL: high-density lipoprotein; non-HDL: non-high-density lipoprotein (Total cholesterol minus HDL-C); AIP: atherogenic index of plasma (log (TG/HDL-C))

angina, ST-segment elevation myocardial infarction (STEMI), or non-ST segment elevation myocardial infarction (NSTEMI).

Data analysis

We analyzed the data using SPSS software version 24 (SPSS, Inc.). Using the cutoffs stated above, we analyzed dyslipidemia as a categorical variable and expressed results as numbers and percentages. We used Chi-square or Fisher exact tests to compare categorical variables and considered a P-value lower than 0.05 statistically significant.

Results

Baseline characteristics

A total of 2097 patients were included in this study, consisting of 1235(58.9%) women and 862(41.1%) men. 51.1% of patients (1072), including 54.3% of women (671) and 46.5% of men (401), had hypertension. Mean age, systolic blood pressure (SBP), fast blood sugar (FBS), HbA1C, 2-hour postprandial (2hpp), and creatinine were higher among men than women. However, mean body mass index (BMI), waist circumference (WC), diastolic blood pressure (DBP), and the duration of diabetes were higher among women than men (Table1).

Dyslipidemia patterns

Approximately 97.81% of patients (2051) had at least one lipid abnormality. 26.61% of patients (558) had isolated dyslipidemia, and 71.2% of patients (1493) had mixed dyslipidemia (dual or triple combination). The most prevalent pattern of dyslipidemia was high AIP (>0.24) (88.0%). The second most common pattern was LDL-C≥70 (80.1%) (Table1).

The most common pattern of mixed dyslipidemia was the dual combination of LDL-C≥70 and high AIP (71.1%). The dual combination of high AIP and low HDL-C was the second most common pattern of mixed dyslipidemia (68.5%) (Table2). Also, 24.7% of patients (518) had triple combination dyslipidemia. The most frequent pattern of triple combination dyslipidemia was the combination of TG≥150, LDL-C≥70, and low HDL-C (<40 in men and <50 in women) (24.7%) (Table3).

We found that 98.14% of women (1212) and 97.33% of men (839) had at least one lipid abnormality. 21.46% of women (265) and 33.99% of men (293) had isolated dyslipidemia. 76.68% of women (947) and 63.34% of men (546) had mixed dyslipidemia (dual or triple combination). The most common pattern in both genders was high AIP (>0.24); 87.8% in women and 88.3% in men. The second most common pattern was LDL-C≥70 and similar among women (81.9%) and men (77.5%).

The most prevalent pattern of mixed dyslipidemia in women and men was the dual combination of LDL-C≥70 and high AIP (>0.24); 72.7% in women and 68.7% in men. The dual combination of low HDL-C and high AIP (>0.24) was the second most prevalent pattern of mixed dyslipidemia in women (64.9%) and men (43.7%).

All patterns of dyslipidemia were more prevalent in women than men, except for high AIP (>0.24). Some of these differences were statistically significant (P-value<0.05).

Table 1 Baseline characteristics of patients

		Total	Women	Men
Age (years)		57.73 ± 10.59 [a]	56.88 ± 10.01	59.03 ± 11.29
The duration of diabetes (years)		8.70 ± 7.54	9.02 ± 7.70	8.27 ± 7.31
WC (cm)		96.26 ± 11.71	96.45 ± 12.29	96.01 ± 10.78
BMI (Kg/m2)		28.55 ± 4.79	29.58 ± 5.01	27.30 ± 4.57
SBP (mmHg)		131.84 ± 20.66	131.68 ± 21.10	132.18 ± 20.64
DBP (mmHg)		78.86 ± 12.11	78.91 ± 12.83	78.83 ± 12.22
FBS (mg/dL)		180.30 ± 73.02	179.96 ± 73.63	180.51 ± 72.00
HbA1C (%)		8.17 ± 1.85	8.13 ± 1.79	8.22 ± 1.93
2hPP (mg/dL)		244.35 ± 100.21	238.24 ± 98.02	252.41 ± 103.08
Creatinine (mg/dl)		1.01 ± 0.29	0.94 ± 0.26	1.11 ± 0.31
TG	**≥150 mg/dl**	957(45.6%) [b]	600(48.6%)	357(41.4%)*
TG	**≥200 mg/dl**	554(26.4%)	337(27.3%)	217(25.2%)
LDL	**≥70 mg/dl**	1679(80.1%)	1011(81.9%)	668(77.5%)*
LDL	**≥100 mg/dl**	877(41.8%)	538(43.6%)	339(39.3%)
HDL	**(<40 mg/dl M & <50 mg/dl W)**	1217(58.0%)	834(67.5%)	383(44.5%)
non-HDL	**≥130 mg/dl**	894(42.6%)	553(44.8%)	341(39.6%)*
AIP	**>0.24**	1845(88.0%)	1084(87.8%)	761(88.3%)

[a]Data are mean ± SD in 2097 patients with type 2 diabetes mellitus

[b]Data are number of patients (prevalence %)

**p-value* < 0.05

WC:waist circumference; BMI:body mass index; SBP:systolic blood pressure; DBP:diastolic blood pressure; FBS:fast blood sugar; HbA1C: hemoglobin A1C; 2hPP:2-hour postprandial; TG: triglyceride; LDL: low-density lipoprotein; HDL: high-density lipoprotein; non-HDL: non-high-density lipoprotein (Total cholesterol minus HDL-C); AIP: atherogenic index of plasma (log (TG/HDL-C))

Table 2 Patterns of dual combination dyslipidemia in the studied population

		Total N(%)	Women N(%)	Men N(%)
TG ≥ 150mg/dl &	**LDL ≥ 70mg/dl**	803(38.3%) [a]	510(41.3%)	293(34.0%)*
TG ≥ 150mg/dl &	**LDL ≥ 100mg/dl**	483(23.0%)	314(25.4%)	169(19.6%)*
TG ≥ 150mg/dl &	**HDL (< 40mg/dl M & < 50mg/dl W)**	631(30.1%)	445(36.1%)	186(21.5%)
TG ≥ 150mg/dl &	**Non-HDL ≥ 130mg/dl**	597(28.5%)	381(30.9%)	216(25.1%)*
TG ≥ 150mg/dl &	**AIP > 0.24**	954(45.5%)	597(48.3%)	357(41.4%)*
TG ≥ 200mg/dl &	**LDL ≥ 70mg/dl**	464(22.1%)	287(23.2%)	177(20.5%)
TG ≥ 200mg/dl &	**LDL ≥ 100mg/dl**	300(14.3%)	190(15.4%)	110(12.8%)
TG ≥ 200mg/dl &	**HDL (< 40mg/dl M & < 50mg/dl W)**	386(18.4%)	264(21.4%)	122(14.2%)
TG ≥ 200mg/dl &	**Non-HDL ≥ 130mg/dl**	394(18.8%)	241(19.5%)	153(17.7%)
TG ≥ 200mg/dl &	**AIP > 0.24**	554(26.4%)	337(27.3%)	217(25.2%)
HDL(< 40mg/dl M & < 50mg/dl W) &	**LDL ≥ 70mg/dl**	944(45.0%)	669(54.2%)	275(32.0%)
HDL(< 40mg/dl M & < 50mg/dl W) &	**LDL ≥ 100mg/dl**	471(22.5%)	348(28.2%)	123(14.3%)
HDL(< 40mg/dl M & < 50mg/dl W) &	**AIP > 0.24**	1179(56.2%)	802(64.9%)	377(43.7%)
AIP > 0.24 &	**LDL ≥ 70mg/dl**	1490(71.1%)	898(72.7%)	592(68.7%)*
AIP > 0.24 &	**LDL ≥ 100mg/dl**	794(37.9%)	489(39.6%)	305(35.4%)*
AIP > 0.24 &	**Non-HDL ≥ 130mg/dl**	839(40.0%)	518(41.9%)	321(37.2%)*

[a]. Data are number of patients (prevalence %)

**p-value* < 0.05

TG: triglyceride; LDL: low-density lipoprotein; HDL: high-density lipoprotein; non-HDL: non-high-density lipoprotein (Total cholesterol minus HDL-C); AIP: atherogenic index of plasma (log (TG/HDL-C)); M. men; W: women

Table 3 Patterns of triple combination dyslipidemia in the studied population

	Total N(%)	Women N(%)	Men N(%)
TG (≥ 150mg/dl) & LDL (≥ 70mg/dl) & HDL (< 40mg/dl M & < 50mg/dl W)	518(24.7%) [a]	372(30.1%)	146(16.9%)
TG (≥ 150mg/dl) & LDL (≥ 100mg/dl) & HDL (< 40mg/dl & M < 50mg/dl W)	289(13.8%)	222(18.0%)	67(7.8%)
TG (≥ 200mg/dl) & LDL (≥ 70mg/dl) & HDL (< 40mg/dl M & < 50mg/dl W)	320(15.3%)	223(18.1%)	97(11.3%)
TG (≥ 200mg/dl) & LDL (≥ 100mg/dl) & HDL (< 40mg/dl M & < 50mg/dl W)	192(9.2%)	144(11.7%)	48(5.6%)

[a]. Data are number of patients (prevalence %)

All *p-values* are < 0.05

TG: triglyceride; LDL: low-density lipoprotein; HDL: high-density lipoprotein; M: men; W: women

Table 4 The most prevalent patterns of dyslipidemia in patients with type 2 diabetes and CAD history

		Total N(%)	Women N(%)	Men N(%)
(Single)				
LDL	**≥ 55mg/dl**	291(88.7%) [a]	124(87.9%)	167(89.3%)
LDL	**≥ 70mg/dl**	225(68.6%)	102(72.3%)	123(65.8%)
AIP	**> 0.24**	287(87.5%)	120(85.1%)	167(89.3%)
(Dual combination)				
AIP (> 0.24) &	**LDL ≥ 55mg/dl**	258(78.66%)	107(75.89%)	151(80.75%)
AIP (> 0.24) &	**LDL ≥ 70mg/dl**	199(60.67%)	88(62.41%)	111(59.36%)
AIP (> 0.24) &	**HDL (< 40mg/dl M & < 50mg/dl W)**	169(51.52%)	94(66.67%)	75(40.11%)
(Triple combination)				
TG (≥ 150mg/dl) & LDL (≥ 55mg/dl) & HDL (< 40mg/dl M & < 50mg/dl W)		73(22.3%)	44(31.2%)	29(15.5%)
TG (≥ 150mg/dl) & LDL (≥ 70mg/dl) & HDL(< 40mg/dl M & < 50mg/dl W)		59(18.0%)	37(26.2%)	22(11.8%)
TG (≥ 200mg/dl) & LDL (≥ 55mg/dl) & HDL(< 40mg/dl M & < 50mg/dl W)		48(14.6%)	29(20.6%)	19(10.2%)

[a]. Data are number of patients (prevalence %)

All *p-values* are < 0.05

CAD: coronary artery disease; TG: triglyceride; LDL: low-density lipoprotein; HDL: high-density lipoprotein; AIP: atherogenic index of plasma (log (TG/HDL-C)); M: men; W: women

Dyslipidemia in patients with T2D and CAD history

A total of 328 (15.64%) patients had CAD history, including 141 (11.42%) women and 187 (21.7%) men. Among this group, high AIP (>0.24) was the most prevalent pattern of dyslipidemia (87.5%), followed by LDL≥70mg/dl (68.6%). Also, the dual combination of high AIP (>0,24) and LDL≥70mg/dl was the most common pattern of mixed dyslipidemia (60.67%). If we categorize LDL-C levels based on the American Association of Clinical Endocrinologists and American College of Endocrinology (AACE/ACE) guidelines [34], LDL-C≥55 was the most prevalent pattern of dyslipidemia among patients with T2D and CAD history (88.7%) (Table4).

Blood lipid profile without threshold

We also plotted the components of the blood lipid profile in terms of 3 independent axes without selecting a threshold (Fig.2). 3-D scatterplots were used to investigate the relationship between TG, LDL-C, HDL-C, and LDL-C, non-HDL-C, AIP. We found that the dots were clustered together in both graphs. These patterns showed that the levels of blood lipid profile components were not within the optimal range in most patients with T2D.

Discussion

In this study, 97.81% of patients had at least one lipid abnormality. In previous studies, the prevalence of dyslipidemia in patients with diabetes has been reported to be 95% in Pakistan [19], 90.7% in south-east Nigeria [25], 90% in Iran [13], 89% in Nigeria [20], and 67.1% in China [22]. Also, we calculated AIP for each patient, which has been shown to predict cardiovascular risk better than its components alone (TG and HDL-C) [35].

The most prevalent pattern of dyslipidemia in the current study was high AIP. Other studies focusing on single dyslipidemia showed that high LDL-C (≥70 or ≥100mg/dl) [19, 24, 26, 29] or low HDL-C (<40mg/dl in men and <50mg/dl in women) [20, 22, 25] were the most common patterns among patients with diabetes. These differences may be due to different genetic predispositions, socioeconomic factors, dietary habits, and medications prescribed in different regions.

Earlier studies have shown that low HDL-C is common among the Iranian population [12, 14]. In the same way, we found that low HDL-C was prevalent in the studied population. The prevalence of low HDL-C in this study was higher than a study conducted among patients with

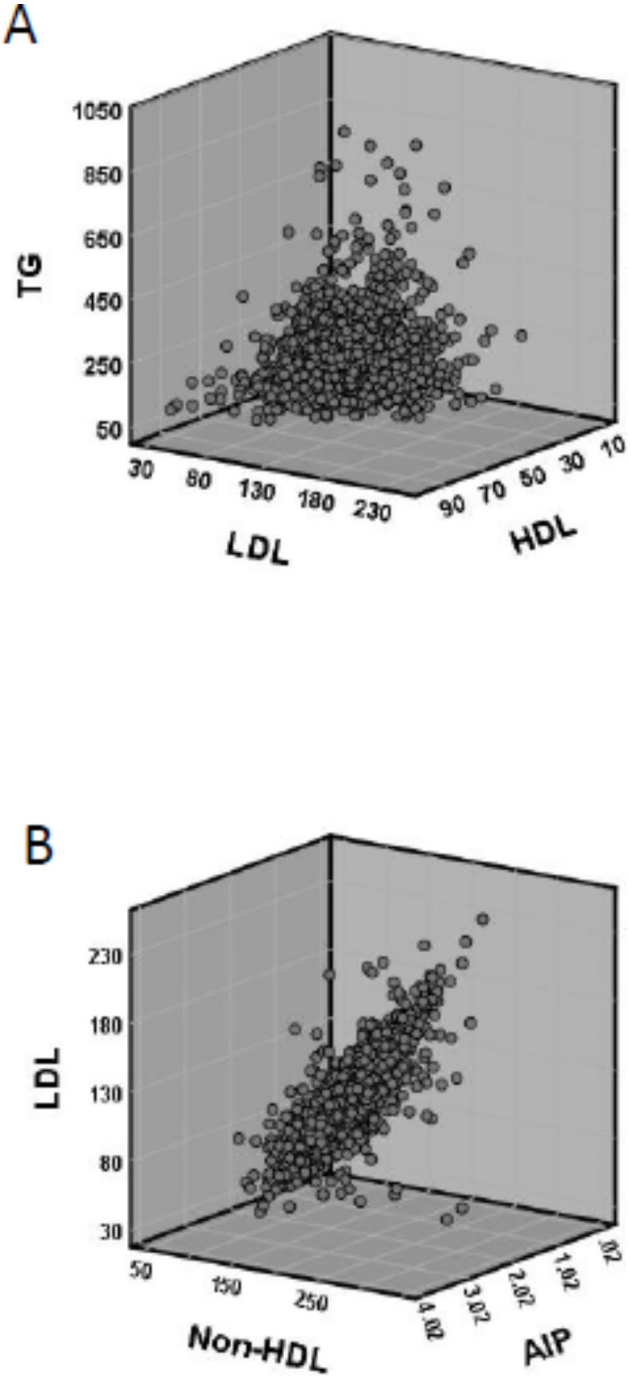

Fig. 2 Relationship between blood lipid profile components. 3-D Scatterplots were used to demonstrate the relationship between (A) TG, LDL, HDL, and (B) LDL, non-HDL, AIP.

The drawn patterns show that the blood lipid levels are not within the optimal range

TG: triglyceride; LDL: low-density lipoprotein; HDL: high-density lipoprotein; non-HDL: non-high-density lipoprotein (Total cholesterol minus HDL-C); AIP: atherogenic index of plasma (log (TG/HDL-C))

diabetes in China (27.6%) [22], while it was less prevalent than in studies conducted among patients with diabetes in Nigeria (62%) and Nepal (64%) [25, 29].

Previous studies focused on patterns of single dyslipidemia, especially high LDL-C, and their association with CVD. However, it has been shown that mixed dyslipidemia, especially combination of high TG (≥150 or ≥200mg/dl) and low HDL-C (<40mg/dl in men and <50mg/dl in women), is also important in CVD risk [36, 37]. Also, the association between dyslipidemia and other disorders, including cancers and microvascular complications (nephropathy and retinopathy), has been reported [10, 11, 38, 39]. Therefore, in addition to CVD, it is worthwhile considering different single and mixed dyslipidemia patterns in different conditions.

The prevalence of mixed dyslipidemia in the current study was 73.87%. We found that the dual combination of high AIP (>0.24) and LDL-C≥70mg/dl was the most common pattern of mixed dyslipidemia (71.1%). Earlier studies showed that the dual combination of high LDL-C (≥70 or ≥100mg/dl) and low HDL-C (<40mg/dl in men and <50mg/dl in women) was the most common pattern of mixed dyslipidemia among patients with diabetes in Pakistan [19], India [28], and United States [40]. Cui et al. demonstrated that the dual combination of TG≥150mg/dl and low HDL-C (<40mg/dl in men and <50mg/dl in women) was the most common pattern of mixed dyslipidemia in patients with diabetes in China [27].

We found that 24.7% of patients had triple combination dyslipidemia, higher than studies conducted in the United States (5.8%) [17] and Pakistan (17%) [19]. The combination of TG≥150mg/dl, LDL-C≥70mg/dl, and low HDL-C (<40mg/dl in men and <50mg/dl in women) was the most prevalent pattern of triple combination dyslipidemia in the current study (24.7%). Earlier studies reported only one pattern of triple combination dyslipidemia, which was the triple combination of TG≥150mg/dl, LDL-C≥100mg/dl, and low HDL-C (<40mg/dl in men and <50mg/dl in women) with a prevalence of 5.8% among the general population in the United States [17] and 17.0% among patients with diabetes in Pakistan [19]. The prevalence of this pattern in the current study was 13.8%.

In the current study, all dyslipidemia patterns were more common among women than men, except for high AIP. Previous studies showed that metabolic disorders, including dyslipidemia, increase after menopause in women [41]. We found that dyslipidemia was common among women and men in patients with T2D. Parikh et al. showed that dyslipidemia was more common among women than men among patients with diabetes in India (97.8% v 85.5%) [28]. In contrast, other studies showed that dyslipidemia was more prevalent among men in patients with diabetes in Pakistan [19], China [22], and Bangladesh [24]. Nakhjavani et al. in Iran reported a more atherogenic lipid profile in women [26]. Other studies conducted in different regions showed that high

TG [21, 23, 27], high LDL-C [21, 22, 40], or low HDL-C [40] were more common among women. Due to the high prevalence of dyslipidemia in women and the association of dyslipidemia with cancer, particularly breast and endometrial cancer [8, 9], more attention is required in women, especially after menopause.

In the current study, high AIP (>0.24) was the most common pattern of dyslipidemia among patients with T2D and coronary artery disease (CAD) history. One study on 514 patients with acute coronary syndrome (ACS) in Iran and another survey of 300 proven patients with CAD in India showed that the most prevalent pattern of dyslipidemia was high TG [42, 43]. If we categorize LDL-C levels based on the American Association of Clinical Endocrinologists and American College of Endocrinology (AACE/ACE) guidelines, LDL-C≥55 was the most prevalent pattern of dyslipidemia among patients with both T2D and CAD history. This difference suggests that high AIP (>0.24) should be considered a significant dyslipidemia pattern in patients with T2D and CAD history.

In this study, we also considered the levels of the components of the lipid profile without choosing a threshold. We analyzed the blood lipid levels in terms of 3 independent axes. The drawn patterns showed that the blood lipid levels in most patients were not optimal and above the therapeutic goal. This indicates that despite the measures and treatments done for patients with T2D, blood lipid levels were still high, and more aggressive efforts, including combination therapy for dyslipidemia, should be considered.

Our limitation was that we did not investigate the prevalence of different patterns of dyslipidemia in patients with cancer or microvascular complications. The association of high LDL-C, high TG, and low HDL-C with CVD, cancers, or microvascular complications has been proved. Further studies can investigate the association between CVD, cancers, nephropathy, and retinopathy with other dyslipidemia patterns (single or mixed) in patients with T2D.

Conclusions

The present study described dyslipidemia patterns among patients with T2D in an Iranian population. We found that a significant number of patients with T2D had single or mixed (dual and triple combinations) dyslipidemia. Diabetic dyslipidemia usually has been discussed in relation to cardiovascular diseases. However, the association between different patterns of dyslipidemia and cancer or microvascular complications should be further investigated. Also, in the current study, high atherogenic index of plasma (AIP) and LDL-C≥70 were the most common patterns, either single or combined, in patients with or without CAD, which suggests that more attention should be paid to these patterns in the follow-up of patients with T2D.

List of abbreviations

T2D	type 2 diabetes.
IDF	international diabetes federation.
ADA	american diabetes association.
AHA/ACC	american heart association/the american college of cardiology.
AACE/ACE	american association of clinical endocrinologists and american college of endocrinology.
NCEP ATP III	national cholesterol education program-adult treatment panel III.
CVD	cardiovascular diseases.
CAD	coronary artery disease.
ACS	acute coronary syndrome.
MI	myocardial infarction.
STEMI	ST-segment elevation myocardial infarction.
NSTEMI	non-ST segment elevation myocardial infarction.
TG	triglyceride.
LDL-C	low-density lipoprotein cholesterol.
HDL-C	high-density lipoprotein cholesterol.
non-HDL-C	non-high-density lipoprotein cholesterol.
AIP	atherogenic index of plasma.
FBS	fasting blood glucose.
2hpp	2-hour postprandial blood glucose.
BMI	body mass index.
WC	waist circumference.
SBP	systolic blood pressure.
DBP	diastolic blood pressure.

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Authors' contributions

MN and AE: Conception and design of the study.
AY and FM: Acquisition of data.
SR and AY: Analysis and interpretation of data.
FM and RQ and AY: Drafting the article.
MN and AE and SR: Critical revision of the article.
All authors read and approved the final manuscript.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Imam Khomeini hospital's institutional research ethics committee approved this study (Ethics code: IR.TUMS.IKHC.REC.1398.270), and we obtained informed consent from all patients.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Authors' information

None.

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References

1. Ogurtsova K, da Rocha Fernandes J, Huang Y, Linnenkamp U, Guariguata L, Cho NH, et al. IDF Diabetes Atlas: Global estimates for the prevalence of diabetes for 2015 and 2040. Diabetes Res Clin Pract. 2017;128:40–50.
2. Sun H, Saeedi P, Karuranga S, Pinkepank M, Ogurtsova K, Duncan BB, et al. IDF Diabetes Atlas: Global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045. Diabetes research and clinical practice. 2021:109119.
3. Ogurtsova K, Guariguata L, Barengo NC, Ruiz PL-D, Sacre JW, Karuranga S, et al. IDF diabetes Atlas: Global estimates of undiagnosed diabetes in adults for 2021. Diabetes research and clinical practice. 2021:109118.
4. Morrish N, Wang S-L, Stevens L, Fuller J, Keen H, Group WMS. Mortality and causes of death in the WHO Multinational Study of Vascular Disease in Diabetes. Diabetologia. 2001;44(2):14.
5. Notarnicola M, Altomare DF, Correale M, Ruggieri E, D'Attoma B, Mastrosimini A, et al. Serum lipid profile in colorectal cancer patients with and without synchronous distant metastases. Oncology. 2005;68(4–6):371–4.
6. Mondul AM, Weinstein SJ, Virtamo J, Albanes D. Serum total and HDL cholesterol and risk of prostate cancer. Cancer Causes Control. 2011;22(11):1545–52.
7. Siemianowicz K, Gminski J, Stajszczyk M, Wojakowski W, Goss M, Machalski M, et al. Serum total cholesterol and triglycerides levels in patients with lung cancer. Int J Mol Med. 2000;5(2):201–6.
8. Kucharska-Newton AM, Rosamond WD, Mink PJ, Alberg AJ, Shahar E, Folsom AR. HDL-cholesterol and incidence of breast cancer in the ARIC cohort study. Ann Epidemiol. 2008;18(9):671–7.
9. Lindemann K, Vatten LJ, Ellstrøm-Engh M, Eskild A. Serum lipids and endometrial cancer risk: results from the HUNT - II study. Int J Cancer. 2009;124(12):2938–41.
10. Jeng C-J, Hsieh Y-T, Yang C-M, Yang C-H, Lin C-L, Wang I-J. Diabetic retinopathy in patients with dyslipidemia: development and progression. Ophthalmol Retina. 2018;2(1):38–45.
11. Kawanami D, Matoba K, Utsunomiya K. Dyslipidemia in diabetic nephropathy. Ren Replace Therapy. 2016;2(1):1–9.
12. Tabatabaei-Malazy O, Qorbani M, Samavat T, Sharifi F, Larijani B, Fakhrzadeh H. Prevalence of dyslipidemia in Iran: a systematic review and meta-analysis study. Int J Prev Med. 2014;5(4):373.
13. Darroudi S, Saberi-Karimian M, Tayefi M, Arekhi S, Motamedzadeh Torghabeh A, Seyedzadeh Sani SMR, et al. Prevalence of combined and noncombined dyslipidemia in an Iranian population. J Clin Lab Anal. 2018;32(8):e22579.
14. Aryan Z, Mahmoudi N, Sheidaei A, Rezaei S, Mahmoudi Z, Gohari K, et al. The prevalence, awareness, and treatment of lipid abnormalities in Iranian adults: Surveillance of risk factors of noncommunicable diseases in Iran 2016. J Clin Lipidol. 2018;12(6):1471–81.e4.
15. Bayram F, Kocer D, Gundogan K, Kaya A, Demir O, Coskun R, et al. Prevalence of dyslipidemia and associated risk factors in Turkish adults. J Clin Lipidol. 2014;8(2):206–16.
16. Khader YS, Batieha A, El-Khateeb M, Al Omari M, Ajlouni K. Prevalence of dyslipidemia and its associated factors among Jordanian adults. J Clin Lipidol. 2010;4(1):53–8.
17. Tóth PP, Potter D, Ming EE. Prevalence of lipid abnormalities in the United States: The National Health and Nutrition Examination Survey 2003–2006. J Clin Lipidol. 2012;6(4):325–30.
18. Joshi SR, Anjana RM, Deepa M, Pradeepa R, Bhansali A, Dhandania VK, et al. Prevalence of dyslipidemia in urban and rural India: the ICMR–INDIAB study. PLoS ONE. 2014;9(5):e96808.
19. Sarfraz M, Sajid S, Ashraf MA. Prevalence and pattern of dyslipidemia in hyperglycemic patients and its associated factors among Pakistani population. Saudi J Biol Sci. 2016;23(6):761–6.
20. Okafor CI, Fasanmade OA, Oke DA. Pattern of dyslipidaemia among Nigerians with type 2 diabetes mellitus. Niger J Clin Pract. 2008;11(1):25–31.
21. Dixit AK, Dey R, Suresh A, Chaudhuri S, Panda AK, Mitra A, et al. The prevalence of dyslipidemia in patients with diabetes mellitus of ayurveda Hospital. J Diabetes Metab Disord. 2014;13:58-.
22. Yan L, Xu MT, Yuan L, Chen B, Xu ZR, Guo QH, et al. Prevalence of dyslipidemia and its control in type 2 diabetes: A multicenter study in endocrinology clinics of China. J Clin Lipidol. 2016;10(1):150–60.
23. Otieno CF, Mwendwa FW, Vaghela V, Ogola EN, Amayo EO. Lipid profile of ambulatory patients with type 2 diabetes mellitus at Kenyatta National Hospital, Nairobi. East Afr Med J. 2005;82(12 Suppl):173-9.
24. Das H, Banik S. Prevalence of dyslipidemia among the diabetic patients in southern Bangladesh: A cross-sectional study. Diabetes & Metabolic Syndrome: Clinical Research & Reviews. 2019;13(1):252–7.
25. Jisieike-Onuigbo NN, Unuigbe EI, Oguejiofor CO. Dyslipidemias in type 2 diabetes mellitus patients in Nnewi South-East Nigeria. Ann Afr Med. 2011;10(4):285–9.
26. Nakhjavani M, Esteghamati A, Heshmat FEA. Dyslipidemia in type 2 diabetes mellitus: more atherogenic lipid profile in women. Acta Medica Iranica. 2006:111–8.
27. Cui R, Qi Z, Zhou L, Li Z, Li Q, Zhang J. Evaluation of serum lipid profile, body mass index, and waistline in Chinese patients with type 2 diabetes mellitus. Clin Interv Aging. 2016;11:445–52.
28. Parikh RM, Joshi SR, Menon PS, Shah NS. Prevalence and pattern of diabetic dyslipidemia in Indian type 2 diabetic patients. Diabetes & Metabolic Syndrome: Clinical Research & Reviews. 2010;4(1):10–2.
29. Thapa SD, KC SR, Gautam S, Gyawali D. Dyslipidemia in type 2 diabetes mellitus. J Pathol Nepal. 2017;7(2):1149–54.
30. Shi W, Neubeck L, Gallagher R. Measurement matters: A systematic review of waist measurement sites for determining central adiposity. Collegian. 2017;24(5):513–23.
31. Detection, NCEPEPo. Third report of the National Cholesterol Education Program (NCEP) Expert Panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III). In: Adults ToHBCi. The Program; 2002.
32. Grundy SM, Stone NJ, Bailey AL, Beam C, Birtcher KK, Blumenthal RS, et al 2018 AHA/ACC/AACVPR/AAPA/ABC/ACPM/ADA/AGS/APhA/ASPC/NLA/PCNA guideline on the management of blood cholesterol: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. Journal of the American College of Cardiology. 2019;73(24):e285-e350.
33. Dobiásová M. [AIP–atherogenic index of plasma as a significant predictor of cardiovascular risk: from research to practice]. Vnitr Lek. 2006;52(1):64–71.
34. Jellinger PS, Handelsman Y, Rosenblit PD, Bloomgarden ZT, Fonseca VA, Garber AJ, et al. American Association of Clinical Endocrinologists and American College of Endocrinology guidelines for management of dyslipidemia and prevention of cardiovascular disease. Endocr Pract. 2017;23:1–87.
35. Dobiasova M. AIP–atherogenic index of plasma as a significant predictor of cardiovascular risk: from research to practice. Vnitr Lek. 2006;52(1):64–71.
36. Agouridis AP, Rizos CV, Elisaf MS, Filippatos TD. Does combination therapy with statins and fibrates prevent cardiovascular disease in diabetic patients with atherogenic mixed dyslipidemia? Rev Diabet Studies: RDS. 2013;10(2–3):171.
37. Halcox J, Misra A. Type 2 diabetes mellitus, metabolic syndrome, and mixed dyslipidemia: how similar, how different, and how to treat? Metab Syndr Relat Disord. 2015;13(1):1–21.
38. Bielecka-Dąbrowa A, Hannam S, Rysz J, Banach M. Malignancy-associated dyslipidemia. Open Cardiovasc Med J. 2011;5:35.
39. Pedersen KM, Çolak Y, Bojesen SE, Nordestgaard BG. Low high-density lipoprotein and increased risk of several cancers: 2 population-based cohort studies including 116,728 individuals. J Hematol Oncol. 2020;13(1):1–11.
40. Cook CB, Erdman DM, Ryan GJ, Greenlund KJ, Giles WH, Gallina DL, et al. The pattern of dyslipidemia among urban African-Americans with type 2 diabetes. Diabetes Care. 2000;23(3):319–24.
41. Stachowiak G, Pertyński T, Pertyńska-Marczewska M. Metabolic disorders in menopause. Przeglad menopauzalny = Menopause review. 2015;14(1):59.
42. Esteghamati A, Abbasi M, Nakhjavani M, Yousefizadeh A, Basa AP, Afshar H. Prevalence of diabetes and other cardiovascular risk factors in an Iranian population with acute coronary syndrome. Cardiovasc Diabetol. 2006;5(1):1–6.
43. Mahalle N, Garg M, Naik SS, Kulkarni MV. Study of pattern of dyslipidemia and its correlation with cardiovascular risk factors in patients with proven coronary artery disease. Indian J Endocrinol Metabol. 2014;18(1):48.

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