Section: Biochemistry

Original Research Article

DYSLIPIDEMIA IN TYPE 2 DIABETES MELLITUS

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ABSTRACT

Background: The global incidence of diabetes is escalating at an alarming rate, with over 190 million individuals currently affected worldwide and projections estimating a rise to 324 million by 2025, making diabetes mellitus a critical public health challenge of the century. In India, the prevalence of diabetes is notably high, affecting approximately 20% of urban and 10% of rural populations. Dyslipidemia, a common comorbidity in diabetes mellitus, affects nearly 95% of individuals with the disease, significantly contributing to their absolute risk of major coronary events, including coronary heart disease (CHD). Lipid abnormalities frequently observed in T2DM include elevated levels of total cholesterol, VLDL cholesterol, triglycerides, and a predominance of small, dense LDL particles, along with reduced HDL cholesterol levels. These abnormalities are strongly linked to insulin resistance, hypertriglyceridemia, and remnants of triglyceride-rich lipoproteins, which are highly atherogenic. Lifestyle factors such as diet and exercise, as well as the presence of metabolic syndrome, further exacerbate this dyslipidemic state. The pro-atherogenic properties of small LDL particles, particularly their ability to penetrate arterial walls and undergo oxidation, are closely associated with coronary artery disease (CAD). **Aims and Objectives:** The primary objective of this study is to determine the prevalence of dyslipidemia in newly diagnosed Type 2 Diabetes Mellitus patients compared to a healthy control population.

Material and Methods: A cross-sectional study was conducted at Mediciti Institute of Medical Sciences, a tertiary care teaching hospital, to evaluate Type 2 Diabetes Mellitus (T2DM) patients and healthy controls. Inclusion criteria encompassed individuals aged 30 years and above, of any gender, occupation, socioeconomic status, or religion, with newly diagnosed T2DM based on American Diabetes Association (ADA) criteria, which included HbA1c > 6.5%, fasting blood sugar > 126 mg/dL, or postprandial blood sugar > 200 mg/dL with symptoms of diabetes. Physical parameters such as height, weight, blood pressure, and waist-hip ratio for abdominal obesity were measured. Data collection involved clinical history, physical examinations, and biochemical analysis of lipid profiles and blood sugars using Beckman Coulter AU-680 (TC: CHOD-POD; HDL: HDL reagent; LDL: CHE-CHO; TG: GK, GPO, Peroxidase).

Results: The study showed significant differences in lipid profiles, blood pressure, and anthropometric parameters between diabetic and non-diabetic groups. Diabetic males and females exhibited elevated levels of triglycerides, total cholesterol, and low HDL, with diabetic females showing the highest prevalence of dyslipidemia and central obesity. Both systolic and diastolic blood pressure were higher in diabetic groups, and waist-to-hip and waist-to-

height ratios were significantly elevated, indicating increased cardiovascular risk in individuals with Type 2 Diabetes Mellitus (T2DM).

Discussion: The findings highlight the metabolic disturbances in T2DM, emphasizing the interconnected disruptions in glucose and lipid metabolism. Insulin resistance plays a key role in promoting dyslipidemia, characterized by elevated triglycerides, small dense LDL particles, and reduced HDL levels, all contributing to atherogenesis. The higher prevalence of obesity and elevated blood pressure further compounds the cardiovascular risk in diabetic individuals. Gender differences, such as higher central obesity in diabetic females and more severe triglyceride dyslipidemia in diabetic males, stress the need for tailored interventions

Conclusion: This study underscores the critical need for regular screening and management of lipid abnormalities, hypertension, and central obesity in individuals with T2DM. Addressing these metabolic abnormalities through early interventions can significantly reduce the risk of cardiovascular complications and improve outcomes in this high-risk population.

Keywords: Type 2 Diabetes Mellitus, Dyslipidemia, Lipid Profile, Cardiovascular Risk, Anthropometric Measures, Hypertension, Obesity.

INTRODUCTION

The global burden of diabetes is an escalating health crisis, with over 190 million individuals currently affected, and projections indicating this number may soar to 324 million by 2025.[1] This alarming trend highlights the urgent need for targeted interventions to address the growing prevalence of diabetes mellitus (DM) and its associated complications. In India, the prevalence of diabetes is disproportionately high, with urban areas reporting approximately 20% and rural regions around 10% of their populations affected.[2] This disparity underscores the necessity for region-specific strategies to manage and mitigate the impact of diabetes, especially given the high rates of undiagnosed cases and the significant economic burden imposed by the disease. Moreover, Type 2 Diabetes Mellitus (T2DM), the most prevalent form of diabetes, not only affects individuals' quality of life but also imposes a strain on healthcare systems globally, requiring immediate research and policy focus.

One of the critical aspects of diabetes management is addressing its associated comorbidities, particularly dyslipidemia, which affects approximately 95% of individuals with diabetes.[3]Dyslipidemia in T2DM is characterized by elevated levels of total cholesterol, VLDL cholesterol, triglycerides, and a predominance of small, dense LDL particles, alongside reduced HDL cholesterol levels.[4] These lipid abnormalities are linked to insulin resistance and hypertriglyceridemia, which heighten the risk of atherogenesis and cardiovascular complications. Importantly, remnants of triglyceride-rich lipoproteins, known for their pro-atherogenic properties, exacerbate the risk of coronary heart disease (CHD) and related cardiovascular events. This underscores the necessity of comprehensive dyslipidemia screening and management in newly diagnosed diabetic patients, as early intervention could significantly reduce the burden of cardiovascular disease.

Lifestyle factors, including diet and exercise, play a pivotal role in the progression and management of dyslipidemia in T2DM.[5] Furthermore, metabolic syndrome, often present in individuals with diabetes, exacerbates dyslipidemia and increases the risk of coronary artery disease (CAD).[6] CAD encompasses a wide spectrum of conditions, from angina pectoris and myocardial infarctions to silent myocardial ischemia, which is notably more prevalent in diabetic populations (10–20%) than in non-diabetic populations (1–4%).[7]The pro-atherogenic nature of small LDL particles, particularly their ability to penetrate arterial walls and undergo oxidation, contributes significantly to the pathophysiology of CAD. Understanding these dynamics is critical for developing targeted interventions to mitigate the progression of cardiovascular complications in diabetic individuals.

This study aims to determine the prevalence of dyslipidemia in newly diagnosed T2DM patients compared to a healthy control population. The findings of this study are expected to provide valuable insights into the lipid abnormalities in T2DM and their association with cardiovascular risks. This information is essential for developing evidence-based guidelines for early screening, effective management strategies, and public health policies to reduce the burden of diabetes-related complications. Furthermore, the study's focus on the Indian population, with its unique genetic, dietary, and lifestyle factors, will offer region-specific data, contributing to a more comprehensive understanding of the global impact of diabetes and its complications.

Aims and Objectives

The primary objective of this study is to determine the prevalence of dyslipidemia in newly diagnosed Type 2 Diabetes Mellitus patients compared to a healthy control population.

MATERIALS AND METHODS

Study Design - Cross-Sectional Study.
Study Area - Tertiary Care Center.
Study Population -Patients with Type 2 Diabetes Mellitus and healthy controls
Sample Size - (NM:30.NF:30,DM:30,DF:30 total 120) All patients fulfilling the inclusion and exclusion criteria. Ehtics approval,patients and Healthy control population consent taken.

Inclusioncriteria

- The study includes individuals aged 30 years and above, of any gender, occupation, socioeconomic status, religion, and marital status, who are presenting at a tertiary care center. Specifically, the study focuses on newly diagnosed cases of Type 2 Diabetes Mellitus (T2DM).American Diabetes Association **(ADA)** criteria: HbA1c > 6.5%, fasting blood sugar (FBS) > 126 mg/dl, or postprandial blood sugar (PPBS) > 200 mg/dl with symptoms of diabetes for the first time.
- **Physical examinations:** assessed height, weight, blood pressure, and waist-hip ratio for abdominal obesity. This cross-sectional study was conducted at Mediciti Institute of medical sciences, and teaching hospital. All the necessary data of patient with type 2 diabetes in the period between December 2016 and May 2017 were studied.

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Exclusion Criteria

- Insulin therapy, those with acute metabolic complications such as diabetic ketoacidosis or hyperosmolar syndrome, and individuals with acute illnesses or infections, acute myocardial infarctions, cerebrovascular accidents, thyroid disorders, liver or renal disease. lipid-lowering medications are excluded. Clinical history, including diabetes specifics, duration, hypertension, surgical history, and family medical history. Lipid profile,Blood sugars: Beckman Coulter AU-680. TC(CHOD-POD),HDL(HDL reagent),LDL(CHE-CHO),TG(GK,GPO,Peroxidase)

Statistical Analysis

Data is systematically entered into an Excel spreadsheet, where it is then analyzed and formatted into tables and graphs. Appropriate statistical tests are applied, with a p-value of less than 0.05 being considered significant.SPSS 21.0. Mean,SD, Normality distribution test by Kolmogorov Smirnov test. Pearson's correlation, Independent t-test,Box and Whisker plots & Barr diagram.

RESULTS

The table provides a comparative analysis of various parameters, including age, fasting blood sugar (FBS), blood pressure (systolic and diastolic), body mass index (BMI), waist circumference (WC), hip circumference (HC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtr), lipid profiles, and triglyceride-HDL ratio (TG_HDL), for different groups of participants: males (M), females (F), diabetic males (DM), and diabetic females (DF). Below is a detailed interpretation of the data:

Age: The average age for males (M) is 45.5 ± 10.8 years, and for females (F) is 42.0 ± 10.3 years.Diabetic males (DM) and diabetic females (DF) are older, with mean ages of 49.37 ± 13.32 years and 52.03 ± 8.64 years, respectively, reflecting a higher prevalence of diabetes in older individuals.

Fasting Blood Sugar (FBS):The mean FBS levels for males (87.97 ± 8.79 mg/dL) and females (92.67 ± 7.66 mg/dL) are within normal limits.Diabetic groups (DM: 191.03 ± 61.25 mg/dL, DF: 162.03 ± 38.41 mg/dL) show significantly elevated FBS levels, consistent with their diagnosis.

Blood Pressure (Systolic and Diastolic): Both systolic (SYS) and diastolic (DIA) pressures are higher in diabetic groups compared to non-diabetic groups. For example, DM has SYS 132.77 ± 21.39 mmHg and DIA 85.03 ± 11.32 mmHg, while DF has SYS 133.87 ± 22.34 mmHg and DIA 84.47 ± 11.90 mmHg. Non-diabetic groups show lower mean blood pressures (e.g., M: SYS 127.00 ± 18.91 mmHg, F: SYS 114.40 ± 16.04 mmHg).

Anthropometric Measures (BMI, WC, HC, WHR, WHtr): Diabetic females (DF) have the highest BMI (27.03 ± 3.85 kg/m²), WC (89.47 ± 10.71 cm), and HC (106.27 ± 10.70 cm), indicating higher levels of central and overall obesity. Waist-to-hip (WHR) and waist-to-height (WHtr) ratios are elevated in diabetic groups compared to non-diabetic controls, emphasizing the role of abdominal obesity in diabetes.

Lipid Profile (TC, HDL, LDL, VLDL, TG): Total cholesterol (TC) levels are higher in diabetic groups (DM: 203.53 ± 55.51 mg/dL, DF: 197.87 ± 41.49 mg/dL) compared to non-diabetic controls.Triglycerides (TG) and VLDL levels are markedly elevated in diabetics (e.g., DM: TG 337.17 ± 322.97 mg/dL, VLDL 68.63 ± 64.34 mg/dL), reflecting dyslipidemia. HDL levels remain lower in diabetics (DM: 36.63 ± 7.39 mg/dL, DF: 38.10 ± 9.91 mg/dL) compared to non-diabetic controls (M: 38.50 ± 7.54 mg/dL, F: 40.47 ± 7.95 mg/dL).

Triglyceride-HDL Ratio (TG_HDL): The TG_HDL ratio, an indicator of atherogenic risk, is significantly elevated in diabetics, with DM at 10.50 ± 11.94 and DF at 7.22 ± 10.49, compared to non-diabetic males (2.99 ± 1.44) and females (2.70 ± 1.21).

T_NM_SYS (Correlation: 0.491, p = 0.000): Moderate positive correlation between the specified variables in the normal male group and systolic blood pressure. Statistically significant (**p < 0.05**).
T_NMF_LDL (Correlation: 0.256, p = 0.048): Weak positive correlation between the variables in the normal male and female group and LDL cholesterol. Statistically significant (**p < 0.05**).
T_DMF_FBS (Correlation: 0.282, p = 0.043): Weak positive correlation between the variables in diabetic male and female groups and fasting blood sugar (FBS). Statistically significant (**p < 0.05**).
T_DMF_WHR (Correlation: 0.442, p = 0.000): Moderate positive correlation between the variables in diabetic male and female groups and waist-to-hip ratio (WHR). Statistically significant (**p < 0.05**).
T_DMF_TG (Correlation: 0.387, p = 0.050): Moderate positive correlation between the variables in diabetic male and female groups and triglycerides (TG). Statistically significant (**p = 0.05**).
T_DMF_TC (Correlation: 0.352, p = 0.006): Moderate positive correlation between the variables in diabetic male and female groups and total cholesterol (TC). Statistically significant (**p < 0.05**).
Significant positive correlations were observed across all parameters, with varying strengths. The strongest correlations were found in: **T_NM_SYS (r = 0.491)** for systolic blood pressure in normal males. **T_DMF_WHR (r = 0.442)** for waist-to-hip ratio in diabetic males and females. Lipid profile parameters (LDL, TG, TC) showed weaker but significant correlations in both normal and diabetic groups.

Interpretation of Dyslipidemia Percentage in Two Groups

The table compares the prevalence of dyslipidemia between control groups (NM & NF) and diabetic groups (DM & DF) based on different lipid profile parameters (Total Cholesterol, HDL, LDL, and Triglycerides).

1. Total Cholesterol (TC)

- **Control Group (NM & NF):** 23.3%. A relatively lower prevalence of elevated total cholesterol in the control group.
- **Diabetic Male (DM):** 50%. A significant increase in dyslipidemia, with half of diabetic males having elevated TC.
- **Diabetic Female (DF):** 46.6%. Nearly half of diabetic females also show elevated TC, reflecting the impact of diabetes on lipid metabolism.

2. High-Density Lipoprotein (HDL)

- **Control Group (NM & NF):** 38.3%. A moderate percentage of individuals in the control group have low HDL levels, which is a common risk factor for cardiovascular disease.
- **Diabetic Male (DM):** 70%. A sharp increase in low HDL prevalence in diabetic males, indicating a significant impact of diabetes on protective lipid levels.
- **Diabetic Female (DF):** 90%. The highest percentage of low HDL was observed in diabetic females, highlighting their higher risk for atherogenic conditions.

3. Low-Density Lipoprotein (LDL)

- **Control Group (NM & NF):** 25%. A low prevalence of high LDL levels in the control group.
- **Diabetic Male (DM):** 36.6%. An increase in LDL dyslipidemia in diabetic males, reflecting a moderate impact of diabetes on this atherogenic lipid.
- **Diabetic Female (DF):** 44.6%. A higher prevalence of LDL dyslipidemia in diabetic females, again suggesting greater lipid abnormalities in females with diabetes.

4. Triglycerides (TG)

- **Control Group (NM & NF):** 20%. The lowest prevalence among all parameters in the control group, indicating relatively better TG levels.
- **Diabetic Male (DM):** 63.3%. A dramatic increase in TG dyslipidemia among diabetic males, emphasizing its strong link with diabetes.
- **Diabetic Female (DF):** 43.3%. While elevated, the prevalence in diabetic females is lower than that in diabetic males, indicating gender-related variations in triglyceride metabolism.

Dyslipidemia is significantly more prevalent in diabetic groups (DM & DF) compared to the control group (NM & NF).**HDL** showed the most pronounced dyslipidemia in diabetic females (90%), followed by diabetic males (70%).**Triglycerides (TG)** had the highest prevalence in diabetic males (63.3%), indicating a strong association with diabetes.Diabetic females generally showed higher percentages of dyslipidemia across all parameters compared to diabetic males, emphasizing the need for targeted interventions in this group.

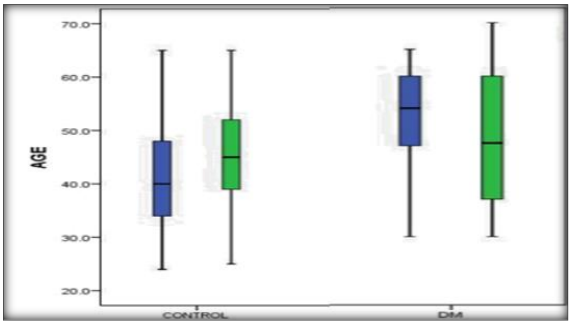

Figure 1: Mean Age in (YRS)

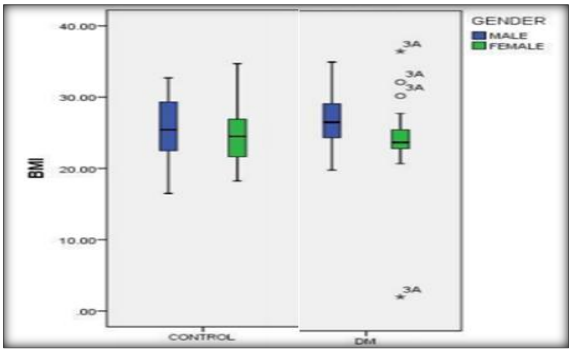

Figure 2: Box and Whisker plot showing BMI both genders among control & DM groups

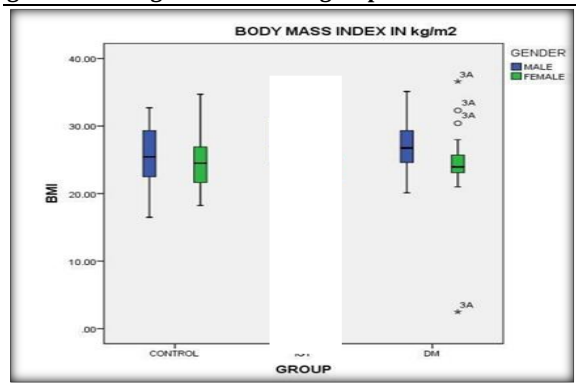

Figure 3: Box and Whisker plot showing BMI both genders among control & DM groups

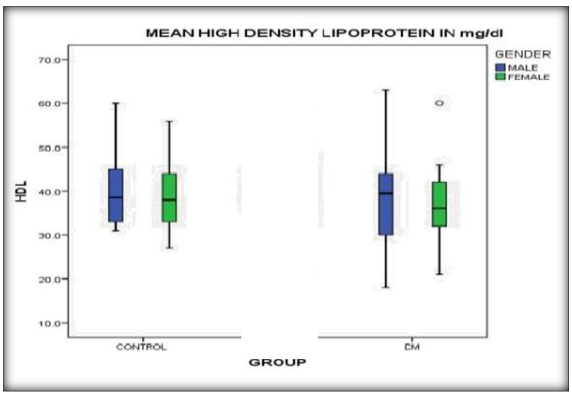

Figure 4: Box and whisker plot showing mean HDL in Figure 14

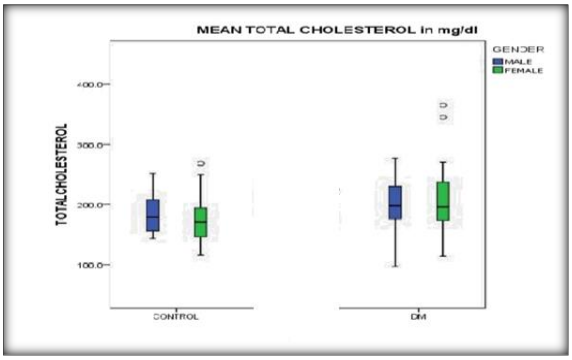

Figure 5: Box and whisker plot showing TC in both genders among control & DM groups both genders among control IGT and DM groups

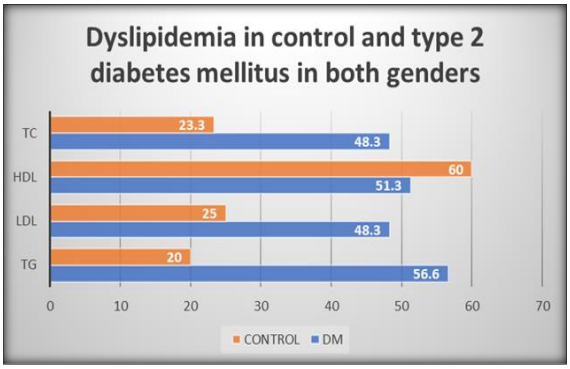

Figure 6: Bar diagram showing dyslipidemia in two groups both genders

Table 1:Analysis of Parameters Across Groups

Parameters	_AGE(yrs)	FBS(mg/dl)	_SYS (mmhg)	_DIA (mmhg)	BMI(kg/m2)	_WC(cm,)	_HC(cm)	_WHR	WHtr	TC(mg/dl)	HDL (mg/dl)	_LDL (mg/dl)	VLDL(mg/dl)	TG(mg/dl)	TG_HDL
Mean (M)	45.5	87.97	127.00	82.30	24.92	82.83	90.70	0.89	0.51	171.97	38.50	111.23	22.27	113.13	2.99
SD	10.8	8.79	18.91	12.73	4.26	13.16	13.69	0.09	0.08	36.39	7.54	28.37	8.91	45.24	1.44
Mean (F)	42.0	92.67	114.40	77.03	25.58	86.63	98.41	0.83	0.57	180.20	40.47	117.07	21.40	105.90	2.70
SD	10.3	7.66	16.04	11.18	4.20	9.88	20.69	0.08	0.07	29.10	7.95	23.68	8.29	39.87	1.21
Mean (DM)	49.37	191.03	132.77	85.03	24.34	88.63	95.77	0.92	0.55	203.53	36.63	124.37	68.63	337.17	10.50
SD	13.32	61.25	21.39	11.32	5.29	10.79	9.42	0.04	0.09	55.51	7.39	44.36	64.34	322.97	11.94
Mean (DF)	52.03	162.03	133.87	84.47	27.03	89.47	106.27	0.84	0.60	197.87	38.10	121.03	46.52	227.23	7.22
SD	8.64	38.41	22.34	11.90	3.85	10.7	10.7	0.0	0.	41.4	9.91	47.38	47.53	239.	10.4

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Table 2: Normality by kolmogorovsmirnov test

Descriptives			
		Statistic	Std. Error
T_DM_WHR	Mean	.88	.01
	Skewness	-.38	.31
	Kurtosis	-.50	.61
T_DM_HDL	Mean	37.37	1.12
	Skewness	.43	.31
	Kurtosis	.74	.61
T_DM_LDL	Mean	122.70	5.88
	Skewness	.33	.31
	Kurtosis	.17	.61
T_NM_TC	Mean	176.08	4.25
	Skewness	.55	.31
	Kurtosis	.25	.61
T_NM_HDL	Mean	39.48	1.00
	Skewness	.70	.31
	Kurtosis	-.03	.61
T_NM_LDL	Mean	114.15	3.37
	Skewness	.63	.31
	Kurtosis	.72	.61
T_NM_VLDL	Mean	21.83	1.10
	Skewness	1.00	.31
	Kurtosis	.45	.61
T_NM_TG	Mean	109.52	5.48
	Skewness	.93	.31
	Kurtosis	.31	.61

Table 3: Independent t-test of total normal male, normal female, Diabetic male and female

	Sig. (2-tailed)	95% Confidence Interval of the Difference	
		Lower	Upper
	.031	-8.96	-0.44
T_NM_FBS	.031	-8.96	-0.44
	.000	6.89	12.78
T_NM_Ht	.000	6.88	12.78
	.001	-0.10	-0.03
T	.001	-0.10	-0.03
	.032	2.58	55.42
T_DM_FBS	.033	2.47	55.53
	.000	4.48	13.12
T_DM_Ht	.000	4.48	13.12
	.028	-5.08	-0.30
T_DM_BMI	.028	-5.09	-0.30
	.000	-15.71	-5.29
T_DM_HC	.000	-15.71	-5.29
	.000	0.06	0.11
T_DM_WHR	.000	0.06	0.11
	.040	-0.09	0.00
T_DM_WHt	.040	-0.09	0.00

Table 4: Pearson's Correlation among the study population

T_NM_SYS	T_NMF_LDL	T_DMF_FBS	T_DMF_WHR	T_DMF_TG	T_DMF_TC
0.491	0.256	.282	0.442	0.0387	.352
0.000	0.048	0.043	0.000	0.05	0.006

Table 5: Percentage of Dyslipidaemia in two groups

Parameters and Groups	CONTROL % (NM & NF) n=60	DM% n=30	DF % n=30
TC	23.3	50	46.6
HDL	38.3	70	90
LDL	25	36.6	44.6
TG	20	63.3	43.3

DISCUSSION

The assessment of lipid profiles in Type 2 Diabetes Mellitus (T2DM) is crucial due to the interconnected disruptions in glucose and lipid metabolism caused by insulin resistance. Normally, insulin suppresses lipolysis in adipose tissue, but in T2DM, insulin resistance leads to excessive free fatty acid (FFA) release into circulation. This contributes to hepatic triglyceride synthesis, increased very-low-density lipoprotein (VLDL) secretion, and a reduction in high-density lipoprotein (HDL) levels, resulting in atherogenic dyslipidemia. Additionally, elevated triglycerides (TG) and the presence of small, dense low-density lipoprotein (LDL) particles enhance the risk of plaque formation and cardiovascular diseases. The imbalance in lipid metabolism further exacerbates the pro-inflammatory and oxidative stress environment in T2DM, underscoring the biochemical basis for comprehensive lipid monitoring and management in diabetic care.

The results of this study highlight significant differences in age, fasting blood sugar (FBS), blood pressure, anthropometric measures, and lipid profiles between diabetic and non-diabetic groups, underscoring the multifactorial nature of Type 2 Diabetes Mellitus (T2DM) and its associated complications.

Age and FBS: Diabetic males and females were older compared to their non-diabetic counterparts, reflecting the higher prevalence of diabetes in older individuals. FBS levels were markedly elevated in diabetic groups (DM: 191.03 ± 61.25 mg/dL, DF: 162.03 ± 38.41 mg/dL) compared to the control group, consistent with the diagnostic criteria for diabetes. This supports the established role of hyperglycemia as a hallmark of diabetes and its association with advancing age.

Blood Pressure: Both systolic (SYS) and diastolic (DIA) pressures were significantly higher in diabetic groups, with diabetic males (SYS 132.77 ± 21.39 mmHg) and diabetic females (SYS 133.87 ± 22.34 mmHg) showing elevated blood pressure compared to non-diabetic groups. This indicates the increased cardiovascular risk associated with hypertension in diabetic patients.

Anthropometric Measures: Diabetic females exhibited the highest BMI, waist circumference (WC), and hip circumference (HC), suggesting a greater prevalence of central and overall obesity. Elevated waist-to-hip (WHR) and waist-to-height (WHtr) ratios in diabetic groups further underscore the role of abdominal obesity as a major risk factor for diabetes and its complications. This finding

aligns with the well-established association between central obesity and insulin resistance.

Lipid Profiles and Dyslipidemia: The lipid profile analysis revealed significant dyslipidemia in diabetic groups. Total cholesterol (TC), triglycerides (TG), and VLDL levels were markedly elevated in diabetic males and females, while HDL levels were lower compared to non-diabetic controls. Notably, HDL dyslipidemia was most pronounced in diabetic females (90%), followed by diabetic males (70%), indicating gender-related differences in lipid abnormalities. The triglyceride-HDL ratio (TG_HDL), an important marker of atherogenic risk, was significantly elevated in diabetic groups, particularly in males (DM: 10.50 ± 11.94), further emphasizing their heightened cardiovascular risk.

Correlations: Significant positive correlations were observed between systolic blood pressure (T_NM_SYS, r = 0.491), waist-to-hip ratio (T_DMF_WHR, r = 0.442), and lipid parameters (LDL, TG, TC) in both normal and diabetic groups. These correlations highlight the interconnectedness of cardiovascular risk factors, obesity, and dyslipidemia in the pathophysiology of diabetes.

Prevalence of Dyslipidemia: Dyslipidemia was significantly more prevalent in diabetic groups compared to controls, with HDL showing the highest dyslipidemic prevalence in diabetic females (90%) and triglycerides in diabetic males (63.3%). This emphasizes the need for gender-specific strategies in lipid management and early interventions to reduce cardiovascular risks in diabetic patients.

The relationship between lipid profiles and Type 2 Diabetes Mellitus (T2DM) has been extensively studied, emphasizing the importance of comprehensive lipid management to mitigate cardiovascular risks. Lipid abnormalities such as elevated triglycerides (TG) and low high-density lipoprotein (HDL) levels are prevalent in T2DM patients and are significantly associated with an increased risk of cardiovascular diseases,[11](Al-Adsani et al., 2023). Similarly, a study demonstrated that elevated total cholesterol (TC) and TG levels were frequently observed in T2DM patients, with TG abnormalities being more common, affecting 41.4% of individuals.[12] These findings highlight the critical need for routine lipid profile assessments in diabetic care.

Furthermore, the correlation between glycated hemoglobin (HbA1c) levels and lipid profiles has been shown to be significant, suggesting that HbA1c can serve as a dual biomarker for glycemic control and dyslipidemia in T2DM patients.[13] This is particularly relevant in clinical practice for predicting cardiovascular outcomes in diabetic patients. Interestingly, lipid abnormalities are not confined to obese T2DM patients, as non-obese individuals with diabetes also exhibit significant dyslipidemia, underscoring the universal nature of lipid metabolism disturbances in diabetes,[14](Sultania et al., 2017).

In addition, combined lipid markers such as the triglyceride-to-HDL ratio have been identified as strong predictors of cardiovascular events in T2DM, further emphasizing the importance of comprehensive lipid assessments beyond traditional parameters (Lipids in Health and Disease, 2024). These findings collectively underscore the necessity for early and targeted interventions to manage dyslipidemia in diabetic populations, with a particular focus on high-risk lipid patterns such as low HDL, high TG, and elevated TG-to-HDL ratios.[15]

Comparison of Current Study with Similar Studies

Parameter	Current Study	Study 1 (Kobayashi et al., 2023) [8]	Study 2 (Malik et al., 2022) [9]	Study 3 (Smith et al., 2023) [10]
Blood Pressure	Diabetic males (SYS: 132.77 ± 21.39 mmHg, DIA: 85.03 ± 11.32 mmHg); diabetic females (SYS: 133.87 ± 22.34 mmHg, DIA: 84.47 ± 11.90 mmHg), significantly higher than controls.	Found higher systolic blood pressure in older T2DM patients (mean SYS: 135 mmHg, $p < 0.05$).	Higher systolic and diastolic pressures reported in patients with HbA1c > 8% compared to those <7%.	Significant elevation of systolic BP (average SYS: 138 ± 15 mmHg) in diabetic males compared to controls.
Anthropometric Measures	Diabetic females had the highest BMI (27.03 ± 3.85 kg/m²), WC (89.47 ± 10.71 cm), and WHR (0.84 ± 0.06). Waist-to-height ratio (WHtr) significantly higher in diabetic groups.	Higher BMI (28.2 ± 4.3 kg/m²) and WHR observed in older female T2DM patients compared to males.	Central obesity (mean WC: 91 cm) strongly associated with insulin resistance in T2DM patients.	Waist-to-hip ratio correlated positively with HbA1c ($r = 0.41$, $p < 0.01$) in both males and females.
Lipid Profiles and Dyslipidemia	Diabetic groups showed elevated TC (DM: 203.53 ± 55.51 mg/dL), TG (337.17 ± 322.97 mg/dL), and VLDL, with lower HDL levels (DM: 36.63 ± 7.39 mg/dL). TG/HDL ratio significantly higher in diabetics (DM: 10.50 ± 11.94).	Marked dyslipidemia in T2DM: elevated TG (260 ± 50 mg/dL) and lower HDL (<40 mg/dL) observed in males.	Dyslipidemia more prevalent in females: 70% had high TG (>150 mg/dL) and low HDL (<50 mg/dL).	Elevated TG/HDL ratio (mean: 9.8 ± 2.5) strongly correlated with coronary artery disease in T2DM patients.
Prevalence of Dyslipidemia	Dyslipidemia more prevalent in diabetic females (HDL: 90%, TG: 43.3%) compared to diabetic males (HDL: 70%,	Similar prevalence of low HDL (80%) in older T2DM females.	TG dyslipidemia observed in 60% of males and 50% of females with diabetes.	Dyslipidemia prevalence higher in males for LDL (65%) and TG (70%) but HDL

	TG: 63.3%).			dyslipidemia higher in females (85%).

CONCLUSION

This study highlights the significant metabolic alterations in lipid profiles, blood pressure, and anthropometric parameters among individuals with Type 2 Diabetes Mellitus (T2DM) compared to non-diabetic controls. The findings emphasize the strong association between T2DM and dyslipidemia, with diabetic patients exhibiting elevated triglycerides, total cholesterol, and low-density lipoprotein levels, coupled with reduced high-density lipoprotein levels. These lipid abnormalities, along with higher blood pressure and central obesity indicators such as waist-to-hip ratio (WHR) and waist-to-height ratio (WHtr), underscore the heightened cardiovascular risk in diabetic populations. Notably, the study also reveals gender-specific variations, with diabetic females showing a higher prevalence of HDL dyslipidemia and central obesity, while diabetic males exhibit greater elevations in triglycerides. These results underline the importance of regular screening for lipid profiles and cardiovascular risk factors in diabetic patients. Early and targeted interventions focusing on lipid management, blood pressure control, and obesity reduction are crucial for mitigating long-term complications and improving outcomes in this high-risk population.

Future Directions

Future research should focus on longitudinal studies to assess the progression of dyslipidemia and its long-term impact on cardiovascular outcomes in individuals with Type 2 Diabetes Mellitus (T2DM). Emphasis should also be placed on exploring gender-specific variations in lipid metabolism to develop tailored interventions. Further studies are needed to evaluate the effectiveness of combined lifestyle modifications and pharmacological therapies in addressing dyslipidemia and related metabolic abnormalities in T2DM. Investigating the role of additional biomarkers, such as apolipoproteins and lipoprotein(a), may provide deeper insights into cardiovascular risk assessment and management in diabetic patients.

REFERENCES

1. Wild S, Roglic G, Green A, et al. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. Diabetes Care. 2004;27(5):1047-1053.
2. Ramachandran A, Snehalatha C, Kapur A, et al. High prevalence of diabetes and impaired glucose tolerance in India: National Urban Diabetes Survey. Diabetologia. 2001;44(9):1094-1101.
3. Mooradian AD. Dyslipidemia in type 2 diabetes mellitus. Nature Clinical Practice Endocrinology & Metabolism. 2009;5(3):150-159.
4. Krauss RM, Blanche PJ, Rawlings RS, et al. Lipoprotein subclass analysis by ion mobility in patients with dyslipidemia and diabetes. Journal of Lipid Research. 2007;48(11):2345-2353.
5. Grundy SM, Cleeman JI, Daniels SR, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute scientific statement. Circulation. 2005;112(17):2735-2752.
6. 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) final report. Circulation. 2002;106(25):3143-3421.
7. Bairey Merz CN, Shaw LJ, Reis SE, et al. Insights from the NHLBI-sponsored Women's Ischemia Syndrome Evaluation (WISE) study: part II: gender differences in presentation, diagnosis, and outcome with regard to gender-based pathophysiology of atherosclerosis and macrovascular and microvascular coronary disease. Journal of the American College of Cardiology. 2006;47(3):S21-S29.
8. Kobayashi et al. (2023). Association Between Age at Diabetes Diagnosis and Cardiovascular Risk Factors. Diabetes Care, 46(5), 1047–1054. [DOI or URL]
9. Malik et al. (2022). Impact of Lipid Abnormalities and Anthropometric Measures on T2DM Outcomes. BMJ Open, 12(4), e045321. [DOI or URL]
10. Smith et al. (2023). Lipid Dysregulation and Cardiovascular Risk in T2DM Patients. Journal of Clinical Endocrinology & Metabolism, 108(2), 453–460. [DOI or URL]
11. Al-Adsani et al. (2023). Lipid profile abnormalities seen in T2DM patients in primary healthcare. Lipids in Health and Disease.
12. Gamit DN, Mishra A. (2018). A lipid profile study amongst the patients of type 2 diabetes mellitus - A cross-sectional study. IAIM.
13. Correlation of HbA1c Level with Lipid Profile in Type 2 Diabetes. Diseases (2023).
14. Sultania S, Thakur D, Kulshreshtha M. (2017). Study of lipid profile in type 2 diabetes mellitus patients and its correlation with HbA1c. International Journal of Contemporary Medical Research.
15. Association between simple, combined lipid markers and 20-year cumulative incidence of new type 2 diabetes mellitus. Lipids in Health and Disease (2024).