Volume 4, Issue 3, 2026

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

A LITERATURE REVIEW OF THE CORRELATION BETWEEN HBA1C AND LIPID PROFILE IN TYPE 2 DIABETIC PATIENTS

Muhammad Hassan Iqbal[1], Adrees Sultan[2], Dr. Ali Husnain Nazar PT[3], Ayla Iftikhar[4], Dr. Samra Asghar[5], Muhammad Adeel[6], Ahtasham Ahmad[*7]

[1]*Riphah International University Faisalaabad*
[2]*Anglia Ruskin University Cambridge*
[3]*University of Sialkot*
[4]*Government College University Faisalabad*
[5]*Riphah International University Faisalabad*
[6]*Imran Idrees Institute of Rehabilitation Sciences, Sialkot*
[*7]*Imran Idrees Institute of Rehabilitation Sciences, Sialkot*

[1]hassaniqbaljutt363@gmail.com, [2]adreessultan@gmail.com, [3]alihusnain101112@gmail.com, [4]aylaiftikhar@gcuf.edu.pk, [5]samra.asghar@riphahfsd.edu.pk, [6]mrmuhammadadeel101@gmail.com, [*7]374ahtasham@gmail.com

DOI: https://doi.org/10.5281/zenodo.21306627

Keywords
Dyslipidemia, Glycemic Control, HbA1c, Lipid Profile, Type 2 Diabetes Mellitus (T2DM)

Article History
Received: 01 February 2026
Accepted: 17 March 2026
Published: 31 March 2026

Copyright @Author
Corresponding Author: *
Ahtasham Ahmad

Abstract

The hallmarks of type 2 diabetes mellitus (T2DM) include chronic hyperglycaemia, insulin resistance and deranged lipid metabolism and represent a global pandemic disorder which results in a heightened risk of cardiovascular disease. Glycated haemoglobin (HbA1c) is a very important indicator of the long-term glycaemic control and has a tendency to grant the development of diabetes dyslipidaemia with resultant abnormalities of the lipid profile that include raised triglycerides, low HDL-C concentrations, and LDL-C. Critical review of 11 articles of 2013-2024 shows that poor glycaemic control (high HbA1c) is still linked to unfavourable lipid patterns. The evidence proves that in those settings where it is difficult to measure cholesterol, HbA1c has the potential to become an indirectly expressed evidence of lipids issues. The study underlines the importance of management of type 2 diabetes, which balances markers of lipids and glycol at once in an effort to mitigate cardiovascular impact. To understand such relations, it is proposed to conduct additional studies.

Introduction:

1. Diabetes Mellitus Overview:

Hyperglycaemia is one of the features of diabetes mellitus (DM), a syndrome of chronic metabolic disease and can be triggered by insulin secretion defects, action defects, or both [1]. It has three major subtypes, which include type 1 diabetes mellitus (T1DM), type 2 diabetes mellitus (T2DM) and gestational diabetes mellitus (GDM). The most widespread type of the disease is type 2 diabetes as around 90% of all cases can be qualified as such [2]. The dynamics of type 2 diabetes is that there is a progressive insulin resistance and the inability of the pancreatic b cells to send adequate insulin in order to maintain insulin sensitivity. The hyperglycaemia becomes permanent and, unless treated, affects the body system through numerous effects which include retinopathy, neuropathy, nephropathy, but most dangerous are cardiovascular diseases (CVDs) [Forbes et al., 2013]. It has a complex nature that is dependent on many factors that include age, poor diet, lack of exercise, obesity, and genetics [Hu FB, 2011]. Diabetes is very high in prevalence and rising rapidly all over the world.

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

The 2021 international diabetes federation (IDF) diabetes atlas shows that there are 537 million individuals between age 20-79 years living with diabetes in the world. It will go up to 643 million and 783 million respectively by the years 2030 and 2045 respectively [5]. The rate is especially high in South Asia and the Middle East, including Pakistan due to dietary changes, urbanization, and rising health awareness; even rural and poor people have an elevated rate [Basit et al, 201617]. Even glucose metabolic disorder is more than type 2 diabetes. Its pathophysiology is complex and complex involving endothelium dysfunction, oxidation, reoccurring redness, abnormalities in lipids as well as insulin resistance [Donath et al., 2011]. In combination, these factors make diabetes one of the leading morbidity and mortality factors across the globe which bring about macro vascular complications such as peripheral vascular disease, coronary artery disease, and stroke, and the microvascular disorders such as the retinopathy, nephropathy, and the neuropathy [Beckman et al, 2002].

2. HbA1c's Significance in Diabetes Monitoring:

The glycaemic control measurement should be done consistently and effectively in responsible diabetes care. One of the most common measures taken by scholars and doctors includes glycated haemoglobin (HbA1c). Without enzyme, the haemoglobin molecule on red cells links up with blood glucose to form HbA1c [Nathan et al., 2007]. HbA1c provides an estimate of average blood glucose over several weeks or few months as red blood cells that formed 120 days ago are on average perished [Sherwani et al., 2016]. The ADA today suggests that HbA1c is the preferred test to use when it comes to diagnosing and monitoring. According to the current recommendations of the American Diabetes Association, one with HbA1c of 6.5 percent or above at two distinct test sessions is assumed to have diabetes [11]. Most non-pregnant adults who are not pregnant should also have clinical goal levels below 7.0 percent as a way of decreasing the chances of developing problems of some sort [12]. Since HbA1c measures long-term glycaemic control, it is more predictive than a one-path measurement level such as fasting plasma glucose (FPG) or random blood sugar (RBS). Moreover, it helps in grading the risk of complications and cannot be affected by such temporary changes caused by stress or meals [Goldstein et al., 2004]. There are a number of studies that have stipulated that the elevated HbA1c is associated with elevated risk of microvascular complications, including diabetic retinopathy and nephropathy [Stratton et al, 2000]. Also, higher levels of HbA1c concentration in isolation have been associated with increased risk of macrovascular disease, especially myocardial infarction and stroke [Selvin et al, 2004]. There are exceptions though. The levels of HbA1c can be influenced by various abnormalities including hemoglobinopathies, anaemia, chronic kidney disease and fresh haemorrhage [English et al, 2015]. Nevertheless, HbA1c remains an important, but not a central part of diabetic management as an operative epidemiological and clinical research biomarker and a choice of modifying treatment strategies [Bonora et al, 2011].

Table 1: HbA1c Classifications

Category	HbA1c Range (%)
Normal	<5.7
Prediabetic	5.7__6.4
Diabetes	6.5__7.0
Diabetes	>7.0

3. The Diabetes Lipid Profile and Its Significance:

Given that the metabolism of glucose and lipids is extremely inter related, a change in one is relevant to the other. This inter-relationship is severely disrupted in patients with type 2 diabetes mellitus (T2DM) caused by chronic insulin resistance and dysfunction of the beta-cells, a situation that causes a downward spiral of upheavals in the metabolic processes [1]. The

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

most frequent metabolism disorder of diabetes type 2 is diabetic dyslipidaemia, a sequence of lipid metabolism that has an extremely high risk of cardiovascular incidents. The presence of hyperglycaemia and lipids in combination with glycaemic control accelerates the evolution of the atherosclerotic vascular disease. Blood tests are commonly used to measure the lipid profiles, which are very significant indicators of risk to cardiovascular among diabetic patients. The most frequently evaluated parameters in such analyses are triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C) and total cholesterol (TC). The characteristic lipid profile is prevalent among the patients with type 2 diabetes: excessive number of small, dense Low density Lipoprotein particles (sdLDL), low levels of High density Lipoprotein cholesterol (HDL-C), and increased triglycerides. This pattern of lipids is the keystone of the insulin resistance syndrome and cannot be viewed as an exclusive diabetic complication [1]. It also varies with the typical non diabetes mellitus hypercholesterolaemia because diabetic dyslipidaemia is characterised by a distinct group of lipid disorders. The worst of the features is the occurrence of the sdLDL particles which are more prone to oxidation and smaller as well as more dense compared to the LDL particles of regular methodology. The decreased values of HDL-C also limit the reverse cholesterol transport activity, and this promotes the concentration of the lipids into the arterial wall [1]. Going on to produce more than enough very-low-density lipoprotein in the liver due to insulin resistance, stimulating release of free fatty acids in the adipose tissue and inhibiting lipoprotein lipase in the peripheral tissues, is a significant contributor to the pathophysiologic substrate of such dyslipidaemia. These alterations in the liver lower the HDL-C and raise the triglycerides in circulation [2]. The reduced insulin action also diminishes Apolipoprotein synthesis and catabolism that contribute to accumulating atherogenic lipoproteins and the abnormal accumulation of lipids [2]. Diabetic dyslipidaemia has a serious clinical value. It plays a significant role in the pathophysiology of atherosclerosis, which is an insidious disease that makes a thick substance accumulate on the walls of vessels. This forms the basis of serious macro-vascular issues that are the principal causes of morbidity and mortality in diabetics, such as ischaemic stroke, peripheral arterial disease and coronary artery disease (CAD) [3]. Diabetes leads to endothelial dysfunction and long-term inflammation that causes more diffuse and more structured atherosclerotic lesions and increased occurrence of thrombotic consequences. Seminal epidemiological studies (such as the Framingham Heart Study) have highlighted the importance of simultaneously treating cholesterol and glycaemic management. This paper demonstrated how the presence of diabetes and dyslipidaemia increases cardiovascular risk catapulting it to a point where it becomes as great as that of a person already diagnosed with coronary artery disease [4]. Indeed, currently, more and more people tend to regard type 2 diabetes as one of the factors which predetermines coronary heart disease, which is why it is necessary to introduce some effective treatment methods.

That is why, according to the current therapeutic recommendations, patients with type 2 diabetes are recommended to be diagnosed and treated fully as early as possible in the case of dyslipidaemia because of this elevated risk. It comprises an appropriate pharmaceutical management, such as fibrates, statins, or combination therapy, depending on the condition, coupled with lifestyle interventions, such as eating habits, physical exercise, and giving up cigarette smoking. Among diabetics, reaching goal lipid levels, i.e. the reduction of LDL-C and non-HDL-C, is a crucial step towards negating risk of cardiovascular disease. Moreover, according to several expert consensus statements, and international guidelines, lipid abnormalities should be included in the central approach to managing type 2 diabetes and cannot be considered a secondary issue compared to other issues. The purpose is to enhance long-term survival and course as well as cut acute cardiovascular events. Therefore, glycaemic control is equally important with regard to lipid profile optimisation in minimising complications related to diabetes and premature deaths [5]. In all, diabetic dyslipidaemia is an important metabolic disorder in type 2 diabetes and poses a major

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

cardiovascular risk. The typical lipid profile such as increased triglycerides, dropped HDL-C and increased sdLDL are among the key contributors of hepatic lipid dysregulation and insulin resistance. As cardiovascular morbidity and death in type 2 diabetes is essentially the product of the atherosclerotic processes related to dyslipidaemia, its existence dictates the prudent and relentless management strategy. Lipid and glucose disorders still need integrated therapy in order to achieve better patient outcomes.

Table 2: Normal and Typical Lipid Profile Values in Individuals with Type 2 Diabetes Mellitus (T2DM)

Lipid Component	Normal Range(mg/DL)	T2DTypical Range (mg/DL)
Total Cholesterol(TC)	<200	>200
Low-Density Lipoprotein(LDL-C)	<100	>130
High-Density Lipoprotein(HDL-C)	>60	<40
Triglycerides(TG)	<150	>200

4. Pathophysiological Link Between Hyperglycaemia and Dyslipidaemia:

Dyslipidaemia, hyperglycaemia and diabetes type 2 are not accidentally related; instead they are the results of one and the same pathophysiological processes, most of which is the insulin resistance [Reaven, 1988]. Insulin is one of the most important hormones that regulate the fat and carbohydrates. Insulin regulates the uptake of glucose to muscle and adipose, suppresses glucose production by the liver, highly discourages adipose tissue lipolysis, encourages fatty acid synthesis and prohibits liver-made very-low-density lipoproteins (VLDL) in healthy individuals [Rader et al, 2014]. Such practices ensure that the level of blood cholesterol and glucose remain under a desirable level.

But in type 2 diabetes and other insulin-resistant diseases this balance is disturbed. One of the most relevant effects of insulin resistance is an increase in triglyceride catabolism in adipocytes that trigger the emission of more FFAs than is possible by the bloodstream. The synthetic rate and secretion of VLDL elevate as these large amounts of these FFAs are then taken up by the liver. The result is hypertriglyceridemia which is a major element of diabetic dyslipidaemia.

Moreover, this amplification of the burden of VLDL triggers a cascade of changes in the structure and metabolism of lipoproteins. Cholesterol ester transfer protein (CETP) is the leading enzyme responsible in mediating of the transfer of triglycerides between the VLDL and the LDL and the HDL particles. This has caused the generation of unstable LDL and HDL which have elevated triglycerides; they undergo rapid catabolism [Chapman et al., 2011]. The deprived triglycerides LDL particles are then thicker and smaller. These heavy, small LDL have a long stay in the artery wall, high sensitivity to oxidation and therefore, being somewhat more permeable, via the endothelium covering, contribute especially to the production of atheroma. HDL particles, which usually serve protective functions as they stimulate reverse cholesterol transport and facilitate the eradication of excess cholesterol on periphery and within atherosclerotic lesions, are at the same time both decreased in numbers and functional capacity. Nonetheless, T2DM poses further risk of getting cardiovascular disease since HDL levels not only decreased but also the activity of the retained particles is compromised [Miller et al., 2011]. Not only does insulin resistance have a variety of metabolic abnormalities leading to permissiveness of lipid diseases but also T2DM persistent hyperglycemia. High concentrations of glucose cause oxidative stress, endothelial dysfunction, and systemic inflammation and augment AGEs as well as ROS production [Brownlee, 2005]. These factors accelerate the process of atherosclerosis, worsen the normal metabolism of lipoproteins, and make the blood arteries deteriorate even more. Insulin resistance, dyslipidaemia and hyperglycemia have a significant interaction effect on the diabetic patients in terms of macrovascular

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

outcomes, peripheral arterial disease, coronary artery disease and stroke.

Therefore, hyperglycemia and dyslipidaemia commingling in type 2 diabetes is not an independent occurrence as foreseen by interconnected metabolic way and conduct. This pathophysiological association should be noted when developing the in-built therapeutic measures. Treatments should address hyperglycemia, as well as lipid imbalances, inflammation, and oxidative stress (to reduce the morbidity of cardiovascular disease in diabetic people).

5. Research on the Association Between Lipid Profile and HbA1c:

To further enlighten the linkage between glycaemic control and lipid metabolism, various studies have looked into relationship between lipid indices and HbA1c levels in patients of diabetes mellitus type 2 (T2DM). The majority have found a very good positive relationship between the increased levels of HbA1c and dyslipidaemia that confers to greater levels of worse lipid imbalance and usually it is linked to worse glycaemic control [Ozder, 2014]. In patients with more HbA1c, Maliha et al. discovered that the levels of HDL-C were significantly lower and triglycerides (TG) and LDL-C were very high in a study conducted on 250 patients in Pakistan with T2DM in 2019. The association was statistically significant ($p < 0.01$) not only to demonstrate the significance of HbA1c as a measure of glycaemic control but also a display of lipid imbalance in diabetes patients. These findings serve to demonstrate that the abnormal lipids and suboptimal glycaemic control have pathophysiological dependence. Similarly, the similarity of the results was supported by a cross-sectional study conducted in India by Chowta et al. which confirmed that as the atherogenic index increased, so did HbA1c, a reported cardiovascular risk parameter, associated with lipids [Chowta et al., 2008]. Where routine lipid measurement is not possible, the direct relationship would enable use of HbA1c as a two-way marker of the degree of dyslipidaemia and more prolonged glycaemic control.

Further, Zargar et al. depicted the possibility of using HbA1c as a substitute of lipid disease. It was found out after doing research that in comparison with patients who had favorable glycaemic control (HbA1c < 7.0%), the values of the LDL-C and TG were significantly higher among patients who had HbA1c > 8.0% [Zargar et al., 2007]. The results are in line with the idea of using the HbA1c level as a surrogate marker to measure cardiovascular risk of patients diagnosed with diabetes, and they confirm the theory that poor glycaemic control is associated with higher atherogenic lipid profile. On the whole both studies show that HbA1c is not only a good measure of chronic glucose control in blood but may also be a viable clinical indicator of predicting dyslipidaemia in type 2 diabetes patients. Co-occurring surveillance and intervention on glycaemic and lipid parameters to prevent cardiovascular problems is also justified by the mounting influence of the interdependence.

6. Diabetes and Dyslipidaemia Epidemiology:

According to the current report by the IDF Diabetes Atlas (2021), approximately one in ten adults around the world are currently diabetic, soaring the cases of the chronic metabolic disease. Occurrence of type 2 diabetes mellitus that causes the most diabetes cases shall keep on rising at a steep increase rate. It is predicted that by 2045, type 2 diabetes mellitus (T2DM) will be the most prevalent type of diabetes and a major concern on global health with an estimated one out of every eight people globally having diabetes [5]. South Asia has the highest incidence of diabetes epidemic. Pakistan is one of the countries which has the highest rates of prevalence rates. Basit et al. (2016) state that 26.7 percent of Pakistanis have diabetes, which significantly overloads the health care system and contributes to the development of complications.

One of the most common and significant of such side effects is dyslipidaemia. It is estimated that between 70 and 85 percent of those who are diabetics with type 2 are afflicted with it, and thus it is a metabolic disorder that virtually all of them are exposed to. The most frequent dyslipidemias include decreased levels of HDL-C and increased triglycerides (hypertriglyceridemia), which significantly contributes to atherosclerotic and other macrovascular diseases [Kharb et al., 2011].

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

Whereas the patterns can differ geographically and according to socioeconomic status, the epidemiologic patterns have shown that dyslipidaemia occurrence is age dependent and is more frequent among female diabetic patients [Li et al., 2021]. Especially, potential interactions are dangerous when dyslipidaemia and hyperglycemia exist together. Lipid abnormalities with high readings of HbA1c, which is indicative of poor glycaemic control, increase substantially the risk of cardiovascular disease (CVD). As manifested in a multitude of studies, dyslipidaemia and inadequate control of glucose are synergistic [Jellinger et al., 2017], which highlights the importance of multimodal approaches towards treatment of diabetes. An overlapping management approach of glucose and lipids is imperative, considering a marketing trend in the increments of type 2 diabetes worldwide and nationally and its evident connection to dyslipidaemia. Early diagnosis, life style modification and drugs are the pillars in minimizing the future cost of cardiovascular morbidity and mortality in diabetic subjects.

Methodology:

The relationship between HbA1c and components of the lipid profile in individuals with type 2 diabetes was explored with a systematic and methodical search of the published peer-reviewed studies published between 2013 and 2024. Keywords such as the set of HbA1c and lipid profile and type 2 diabetes and dyslipiaemia were used in searching across the databases including PubMed, Google Scholar, Science Direct, and Scopus.

They contained the papers where the quantitative data on lipid and HbA 1c markers were described and showed a statistical association; their authors wrote papers in English and they studied people with type 2 diabetes. Non-statistical data, case reports, studies on Type 1 and gestational diabetes, poor records, and exclusion were also made. Among the reviewed amount of publications that initially were analyzed with the inclusion/ exclusion criteria, ten pertinent articles have been chosen. One of the data collected on a study would be the sample size, type of the study, mean HbA1c, lipid levels and the correlation outcomes. To diagnose the patterns of the repeated links between the lipid abnormality and glycaemic control concerns, the study considered the tendencies in the research. No ethical permission was necessary since only published information was utilised.

Review Body:

The correlation between HbA1c and total cholesterol (TC):

One of the lipoprotein particles that are used to conduct total cholesterol (TC) includes low-density lipoproteins (LDL), very-low-density lipoproteins (VLDL), intermediate-density lipoproteins (IDL), and high-density lipoproteins (HDL). Although, on its own, the measurement of total cholesterol cannot discriminate between these atherogenic and protective fractions, a consistently high level of TC, particularly when accompanied by high LDL-C and low HDL-C, is directly associated with the occurrence of atherosclerosis, rising arterial rigidity, and the rising risk of heart events. There are increased risks in persons with Type 2 Diabetes Mellitus (T2DM) since there are metabolic abnormalities that influence the lipid and glucose pathways. There is mounting data to support the notion that TC levels have a positive correlation with a long-term marker of glycaemic control HbA1c in T2DM patients. This affiliation reinforces universal metabolism, such as press insulin resistance and liver mishandling. Healthy individuals In healthy individuals insulin does not only stimulate the intake of glucose but it also helps sustain lipid homeostasis by inhibiting the synthesis of cholesterol in the liver and encouraging the synthesis of LDL receptors that clear blood of cholesterol. In some insulin-resistant disorders like type 2 diabetes, however, the hepatic cholesterol-suppressing power of insulin is reduced. The endogenous hypercholesterolaemia is hastened due to augmented action of HMG-CoA reductase, which is the enzyme that causes moderation of the rate-limiting step in the generation of cholesterol.

Also, insulin resistance increases the clearance of LDL particles delaying their exit and prolongs their circulation through reduced production and number of LDL receptors. In addition to increasing the total levels of

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

cholesterol and triglyceride-enriched LDL particles, the overproduction of VLDL in liver, which begins in response to excess fatty acids and glucose molecules as substrates, makes the LDL particles more dense, more compact, and higher in atherogenicity. This relationship has been measured in different clinical studies. A direct correlation of poor glycaemic control and hypercholesterolaemia was indicated by Khan et al. (2020), as one example. The level of total cholesterol was significantly higher in patients with HbA1c > 8 percent as compared to the well-controlled (HbA1c < 7 percent), which meant that there was a strong relationship between sustained hyperglycemia and abnormal cholesterol metabolism. Similarly, Rahman et al. (2017) have found a positive moderate correlation ($r = 0.39$, $p < 0.01$) between HbA1c and TC in the setting of population of people with diabetes in Bangladesh, which confirms that a rise of total cholesterol is linked with worsening glycaemic control. There is also a second way through which diabetes raises cholesterol levels, besides altering production and clearance, glycation of lipoproteins. Due to persistent hyperglycaemia, the major structural component of LDL, apolipoprotein B-100 becomes non-enzymatically glycated. By reducing the ability of LDL particles to be removed by receptors this structural situation damages the idea of hepatic uptake and raises the concentrations of cholesterol within the plasma. Further, since glycated LDL can be oxidised easily, it is also more cytotoxic and atherogenic to endothelial cells which heightens vascular dysfunction and inflammation.

Moreover, glycation and functional impairment of HDL particles restrict the capacity of the body to eradicate excess cholesterol located in peripheral tissues and atheromatous plaques hence lowering its effectiveness in the reverse cholesterol transport. It is this dual effect of impaired HDL functionality and impaired uptake of LDL that compounds the effects of lipid accumulation in the endothelium of the arteries that reinforce the formation of plaque and cardiovascular issues.

Although the TC offers a broad indicator of lipid status, it can be partially tripled by being used in conjunction with LDL-C, HDL-C, and triglycerides (TG) levels as well as using calculated ratios of lipoproteins, namely, TC/HDL-C and LDL-C/HDL-C calculations. The generated indices have an enhanced predictive capacity of cardiovascular risk stratification in individuals with type 2 diabetes where mixed dyslipidaemia is very frequent and can be overshadowed by single readings. So, to sum up, high total cholesterol in patients with type 2 diabetes is not an independent phenomenon but accompanies a complex metabolic disorder, which consists of insulin resistance, dyslipoproteinemia, and chronic hyperglycaemia. The interdependency of the glucose and lipid metabolism came to the light through TC and HbA1c relationship indicating impressions of a close metabolic follow up and control. Both dyslipidaemia and hyperglycaemia should be managed at the same time in order to prevent atherosclerosis and the heavy loads of cardiovascular disease in this vulnerable group.

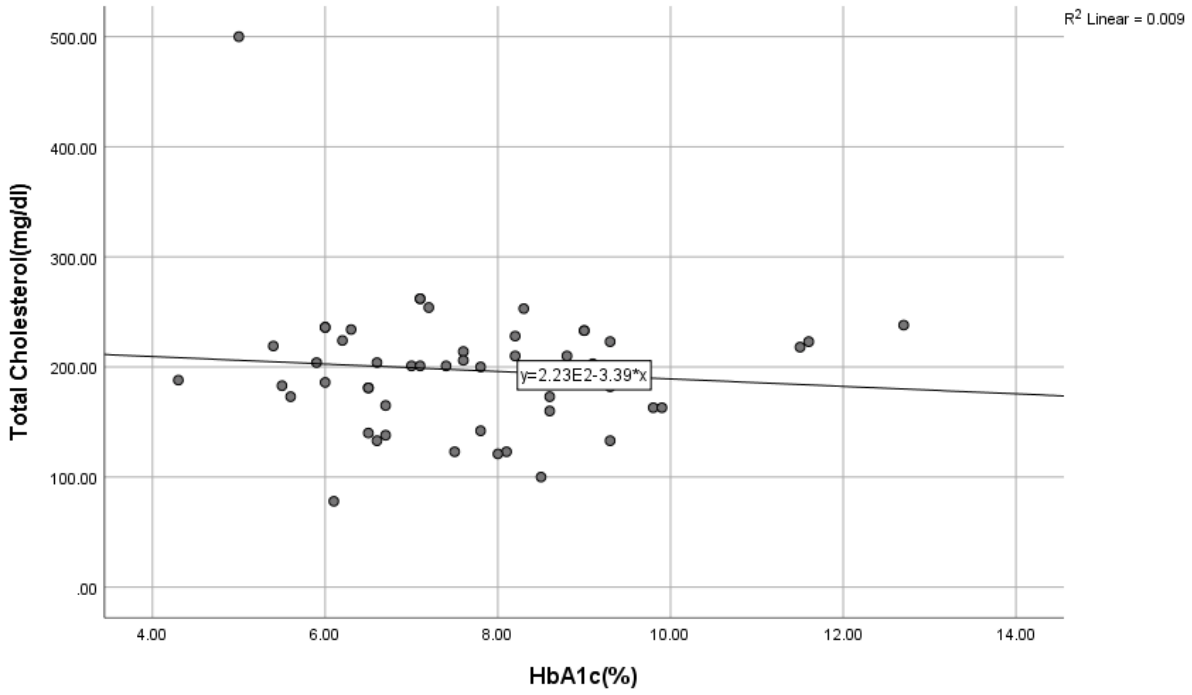
1. The correlation of HbA1c with total cholesterol (TC):

The sum of the amount of cholesterol in all the lipoprotein particles; like low-density lipoprotein (LDL), high-density lipoprotein (HDL) and very-low-density lipoprotein (VLDL) is known as total cholesterol (TC). Although TC alone is not very strong predictor of risk of cardiovascular diseases, repeatedly higher TC levels have been exceptionally linked to heightened atherogenesis and cardiovascular morbidity, especially in the type of low HDL-C and high LDL-C. There are some indications that, total cholesterol and HbA1c are positively correlated in individuals with Type 2 Diabetes Mellitus (T2DM). Poor glycaemic control leads to hypercholesterolaemia and in hepatic production of cholesterol, down- regulation of LDL receptors. Insulin resistance is a characteristic feature of type 2 diabetes and increases the activity of enzyme HMG-CoA reductase that controls the synthesis of cholesterol. As an instance, Khan et al. (2020) reveal that the TC was significantly elevated in the patients with HbA1c >8 compared to patients with HbA1c <7, which means that there is a relationship between hyperglycaemia and hypercholesterolemia. Rahman et al. (2017) using the similar population of Bangladesh attained slightly positive ($r = 0.39$, p

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

< 0.01) correlation of TC and HbA1c. In addition, mismanaged diabetes leads to lipoprotein glycation increasing the concentration of blood lipids and blocking the receptor-mediated clearance. TC is however, often more clinically significant when it is viewed with the aid of the lipid subfractions since it comprises both the beneficial and hazardous fractions (HDL and LDL, VLDL).



P value (0.514)
R2 (0.009)

2. The relationship between low-density lipoprotein cholesterol (LDL-C) and HbA1c:

It is quite common knowledge now that low-density lipoprotein cholesterol (LDL-C) is the atherogenic lipoprotein that transfers cholesterol produced in liver to the periphery. Overabundance of LDL-C is strongly linked with atherosclerosis development and progression process even though the latter is also indispensable to hormone production and cell preservation. The above process is highly worsened in individuals with type 2 diabetes mellitus (T2DM) as they have underlying metabolic disturbances insulin resistance and persisting hyperglycaemia.

LDL-C is deposited in the artery intima and leads to intimal dysfunction and the accumulation of the platelets forming plaque and the formation of foam cells which are the first markers of the atherosclerotic lesions. Additional aid to the atherogenicity of LDL-C is created through the process of glycation and oxidation in type 2 diabetes through a non-enzymatic pathway. Since glycated LDL possesses diminished affinity to hepatic LDL receptors, it remains in circulation, and thus is more prone to oxidation alterations. The oxidised LDL (oxLDL) enhances the rate of vascular damage, carries initiating inflammatory cascades, and is immunogenic.

Several studies have shown that there is a crucial association involving HbA1c and LDL hepatic concentrations, which provides evidence to the interaction of lipid metabolic system and glycaemic control. Such is the case of Maliha et al. (2019) who found a significant correlation ($r = 0.52$, $p < 0.001$) between a high level of LDL-C and higher levels of HbA1c exceeding the threshold in T2DM patients living in Karachi. The above results indicate that suboptimal glycaemic control could be an indication of further abnormal lipids, specifically high LDL-C.

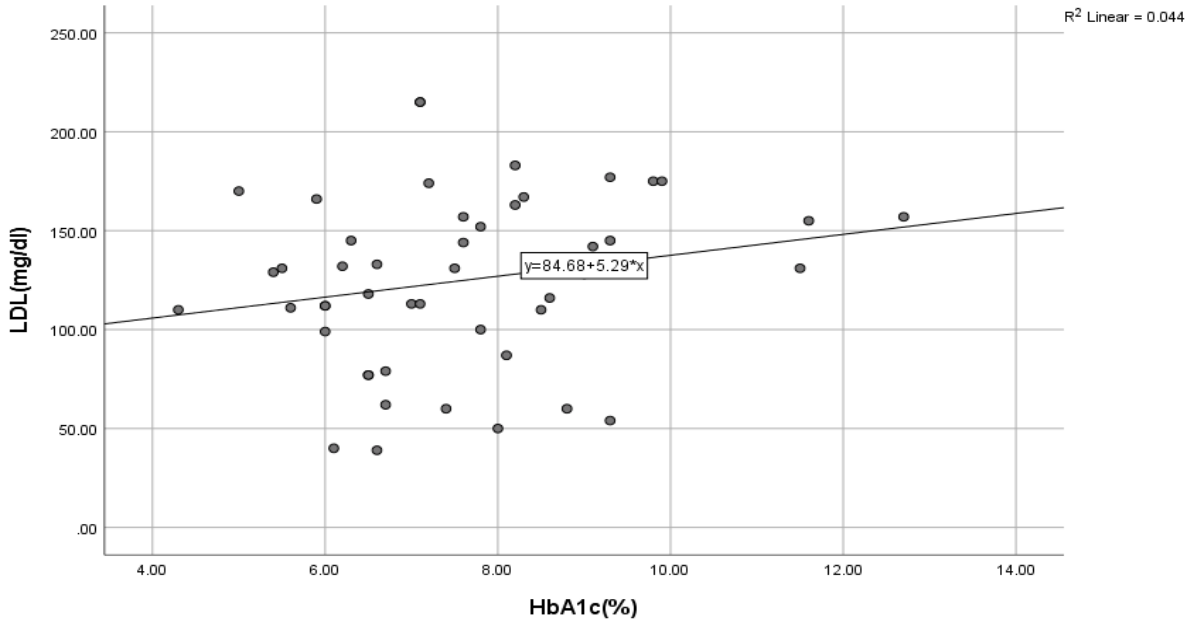
Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

Mechanistically, insulin resistance is the door to this interrelation. Insulin leads to an increase in the number of LDL receptors on hepatocytes increasing the circulating LDL-C clearance within healthy people. But in the state of insulin-resistance, reduced activation of LDL receptors LDL seen in the blood means that LDL has a longer half-life and reduced clearance by the liver. This elevates the LDL-C and the duration in which these particles can suffer atherogenic modifications.

Besides, oxidative status is common in diabetic patients due to current hyperglycaemia. When oxidation occurs in the native LDL it becomes a strongly pro-inflammatory and cytotoxic particle, known as oxLDL which accelerates endothelial destruction and inflammation of the vascular tissue making this process catalyzed by the production of reactive oxygen species. The presence of these mechanisms make it understandable why type 2 diabetes patients are often poorly controlled with respect to LDL-C level and glycaemic control. This association is especially clinically relevant due to the increasing rate of early-onset dyslipidaemia and insulin insensitivity in South Asians. Underlying this finding, the levels of LDL-C were higher in South Asians who also had more of the tiny, dense LDL particles, even when HbA1c also rose somewhat, as Misra et al. (2014) assert. Along with these LDL particles being more atherogenic, they are also more prone to oxidation and thus much less susceptible to removal by receptor-mediated means, which is a risk factor of cardiovascular disease. It is necessary to note, though, that not all studies do oxbridge literary review find a significant correlation between LDL-C and HbA1c at all times. Confounding elements such as receiving lipid-reducing medicine (statins, e.g.), personal variation in fat consumption, activity rates, or gene alterations related to lipid metabolism may devote to disparate or soft associations in some studies. Such confounding factors make it more difficult to perceive the actual correlation between LDL-C levels and glycaemic control, and this means that risk assessment should be personalised.

Considering all this, LDL-C has an important role in atherogenesis, across stages of glycemic levels and it increases due to mismanagement of diabetes as a result of insulin resistance and oxidative stress due to excessive blood sugar. This need to coordinate regulation of glycaemic and lipid parameters to minimize the risk of macrovascular complications of type 2 diabetes is reflected in the alpha values of over 0.4 representing an exceedingly strong correlation between HbA1c and LDL-C and, in South Asians, is biggest of all. In spite of the heterogeneity in the results due to confounding factors, the overwhelming strength of the evidence supports LDL-C as an index and mediator of cardiovascular risk in diabetes.



Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

P value (0.142)
R2 (0.044)

3. High Density Lipoprotein Cholesterol (HDL-C) and HbA1c:

High-density lipoprotein cholesterol (HDL-C), is a significant cardiovascular preventive element, towards which a variety of processes depends. These contain anti-inflammatory actions that prevent inflammation of vascular tissues, endothelial regeneration processes that maintain vascular integrity and prevent oxidative damage, and reverse cholesterol transport whereby cholesterol in the peripheral tissues finds a way back to the liver to be evacuated. The HDL prevents the occurrence of atherosclerosis as it also possesses the antithrombotic and the antioxidant effect.

Nevertheless, the HDL-C quality and the quantity are extremely impaired in patients with T2DM. The concentration of HDL-C is often reduced in diabetic patients, although more importantly, HDL particles functionality is impaired. Glycation of HDL components by hyperglycaemia reduces the ability of the particle to sustain endothelial physiology, to limit inflammation, and to promote cholesterol efflux.

This relationship is supported by the inverse relationship between HDL-C and HbA1c documented by different clinical researches. In particular, Ramesh et al. (2018) revealed that patients with HbA1c above 9% invariably had significantly low levels of HDL-C in comparison with patients who had much controlled diabetes. There was a moderate inverse relationship ($r = -0.45$, $p < 0.01$) in the trial, which means that the HDL-C level diminished correspondingly with augmented hyperglycaemia.

The decrease of HDL-C in type 2 diabetes is one of the main reasons which is connected with elevated cholesterol ester transfer protein (CETP) activity. VLDL transfer of triglyceride to HDL is mediated by CETP and results in enlargement of HDL into triglyceride rich particles. Such TG-rich HDL particles lower total HDL-C because they have a defective structure and are rapidly removed from circulation. There is also the impairment of reverse cholesterol transport and antioxidant activity of these particles. Insulin resistance, which is characteristic of type 2 diabetes, is another variable that adversely influences production of hepatic apoA-I, which forms a part of HDL. The low production of apoA-I reduces formation and assembly of the HDL particles whose overall result is low HDL-C formation and impaired HDL. Insulin resistance also plays a role that worsens cardio-protective effect of HDL and also alters enzymatic pathways that mediate HDL remodelling.

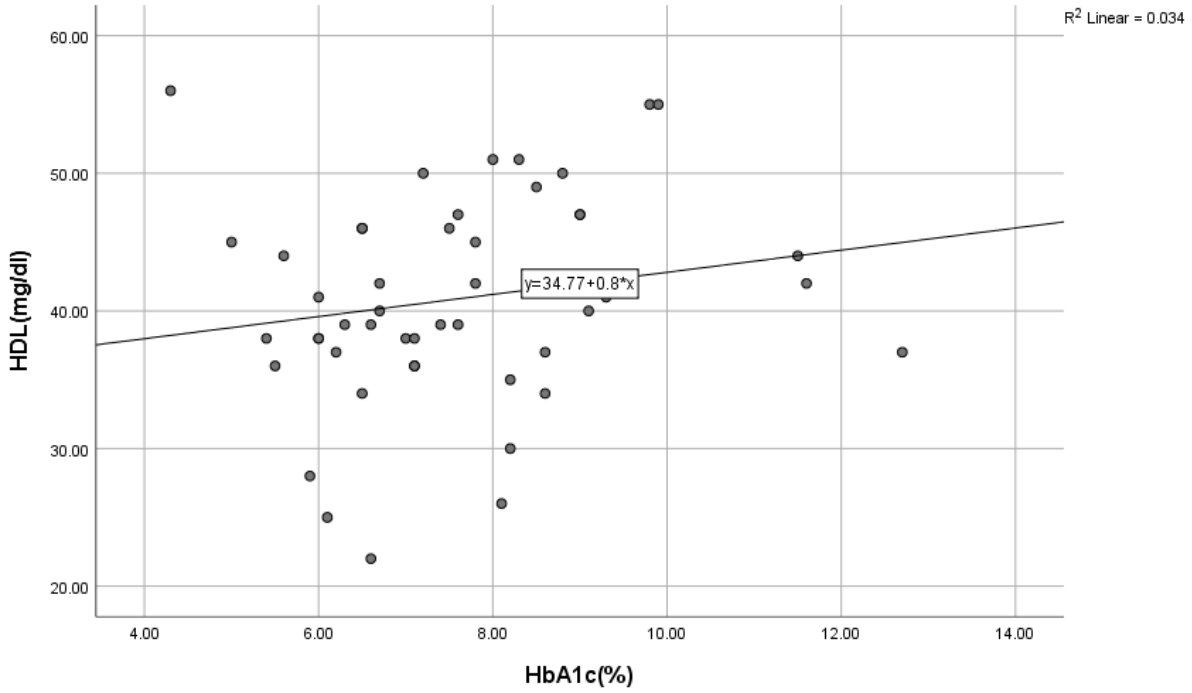
The quantitative evidence of such an analysis obtained in studies taking place at a bigger scale and the correlation between HbA1c and HDL-C is also quantitatively proven. The meta-analysis is consistent across studies, demographics, and 2022 meta-analysis that HDL-C levels lowered by around 3-5 mg/DL as a result of each 1 percent rise in HbA1c, displaying stable adverse relation. The net effect of the long-term presence of hyperglycaemia on lipid metabolism and cardiovascular risk is brought up by the decrease in HDL-C in accompaniment with the aggravation of glycaemic management.

The two-way relationship between HDL-C and HbA1c is uniform amongst the populations, nevertheless ethnicity variations will influence baseline HDL-C and HDL-C responsiveness to glycaemia. An example of this contradiction can be given of South Asians having lower HDL-C levels and more faulty HDL particles and an augmented load of cardiovascular disease, with only modest gains in HbA1c.

To sum up, HDL-C is a critical defence mechanism against atherosclerosis, however, HDL-C levels and functions become much lower in individuals with type 2 diabetes and especially in those with poor glycaemic control. Such effects as the different LPs metabolism, CETP activity, and insulin resistance related impaired synthesis of apoA-I may be factors influencing the same negative association between the HDL-C and HbA1c. To reduce the cardiovascular risk among diabetics, HDL-C along with HbA1c should be monitored and interventions to enhance the latter should be applied. glycaemic management and HDL functionality.

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593



P value(0.199)
R2 (0.034)

4. Triglycerides (TG) and HbA1c:

Triglycerides (TG) in diabetics with type 2 diabetes mellitus (T2DM) constitute the most consistently and strongly connected lipid parameter in relation to glycaemic control or rather HbA1c. No lipid fraction is linked more strongly and consistently positive with rising hyperglycaemia than TG. The molecular mechanisms of this relationship are the metabolic abnormalities that define type 2 diabetes, insulin resistance and the abundance of circulating free fatty acids (FFAs).

Insulin in the insulin-sensitive human being inhibits hepatic excessive production of TG-enriched lipoproteins known as VLDL and adipose tissue lipolysis. In type 2 diabetes, however, under insulin resistance, there is no control over adipocyte lipolysis leading to a large magnification of the supply of FFA to the liver. These FFAs lead to increased TG in circulation through raising hepatic manufacturing of VLDL particles and also being precursors of triglyceride generation. Clear evidence of this relationship was demonstrated by Kumar et al. (2021) in a study that involved 400 T2DM patients. The authors obtained a significant positive correlation between TG and HbA1c ($r = 0.61$, $p < 0.001$). The average TG levels were significantly low in the patients with good glycaemic control as well as with HbA1c levels more than 200 mg/DL. The trend is an indication that poorly controlled glycaemia is the immediate factor that increases hypertriglyceridemia.

The elevation of TG in T2DM is triggered by the elevated synthesis and insecure elimination. There is a loss of lipoprotein lipase (LPL) an enzyme which hydrolyses triglycerides beginning with the VLDL and chylomicrons in insulin-resistant conditions. This reduces break down or removal of TGs and this intensifies hypertriglyceridemia. Overall, the net effect on individuals with poorly controlled diabetes is that the levels of TG level will rise steadily and significantly.

In addition, high TG levels profoundly affect other classes of lipoproteins on the downstream. When LDL is exposed to high TG levels, small dense LDL (sdLDL) are generated, detectable, more readily oxidatively modified, and much more atherogenic. This is when HDL particles that are TG-rich are removed promptly and effectively broken down, resulting in low levels of HDL-C and impaired reverse cholesterol transport. Such effects make the lipid profile very atherogenic and divert

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

cardiovascular risk among type 2 diabetic patients.

This dyslipidemic trend has been recorded to occur in various ethnic and cultural groups. Those studies (Alam et al., 2019, Olatunde et al., 2018, Sharma et al., 2020) show that Rise TG and HbA1c are positively correlated and statistically significantly correlated with one another. The results of these analogous tendencies in different regions validate the functionality of TG as a sign of glycaemic control and cardiovascular danger.

Altogether, triglycerides represent a biomarker and metabolic and vascular dysfunction modulator in the frame of type 2 diabetes. They also synergize with the other lipid fractions to promote atherogenesis and their rise can be due to insulin signalling impairment along with the inability to control lipolysis. The screening of total lipids is supported as the correlation between TG and HbA1c is strong and reproducible across all the populations, especially in the recently diagnosed patients with diabetes with poor control. To achieve long-term benefit and decrease cardiovascular risk in those at-risk patients, therapeutics that respond to glycaemic control, as well as those that respond to a reduction in triglyceride levels (e.g., lifestyle measures, insulin-sensitising agents, and fibrates), are warranted.

5. Atherogenic Lipid Ratios and HbA1c:

In comparison with the single lipid tests, lipid ratio or composite measures, which are based on combinations of individual lipid components, provides a more complete risk portrait in the cardiovascular environment. There has been common acceptance that lipid ratios provide better evidence of cardiovascular disease (CVD) and metabolic derangement in patients with type 2 diabetes by indicating the ratio of atherogenic (pro-atherosclerotic) to anti-atherogenic (protective) lipoproteins. The most commonly evaluated and clinically important ratios are the triglyceride (TG)/HDL-C ratio, the total cholesterol (TC)/ HDL-C ratio and LDL- C/HDL-C ratio.

The TG/HDL-C ratio is especially important in diabetic scenario, and all the ratios supply details on protective HDL-C levels and atherogenic load of lipids. The ratio serves as a surrogate measure of insulin resistance not only but also enshrines the impact of adverse co-occurrence of low HDL-C and hypertriglyceridemia which are two characteristics of diabetic dyslipidaemia. More specifically than any one measurement of lipid level, ratio defines the interaction between glucose and lipid abnormalities at the metabolic level.

The TG/HDL-C ratio may be an early predictive parameter of glycaemic dysregulation and cardiovascular disease risk since studies have reported that it is more closely related to HbA1c than individual lipid parameters. In yet another case, the TG/HDL-C ratio was strongly correlated but positively with HbA1c ($r = 0.65$) as revealed by the study carried out by Singh et al. (2022); this shows that the higher this ratio becomes abnormal, the worse glycaemic control will be. This demonstrates the importance of TG/HDL-C ratio in stratifying the risk and also in the evaluation of metabolic severity of type 2 diabetes.

TG/HDL-C ratio is also postulated as an indirect evidence of insulin resistance, particularly in lean or regular patients with a probable lack of noticeable cardiometabolic danger. Elevated TG/HDL-C ratios in insulin-resistant patients usually reflect abnormal hepatic overproduction of lipoproteins rich in triglycerides and impaired metabolism of HDL, as those occurring in insulin-resistant disorders. Lipid ratios are cheap,fast effective and can be used to determine cardiometabolic risk in an environment where the healthcare system has limited resources and cannot engage in complex lipid fractionation and direct measurement of insulin sensitivity. With the addition of HbA1c reading, one can also distinguish the patients, who should receive aggressive lifestyle change or pharmacological intervention prior to the overt impairment. Finally, it can be noted that lipid ratios, i.e. TG/HDL-C, provide a superior report of the cardiovascular risk of lipids in type 2 diabetes. Lipid metabolism and glycaemic control are connected since they are closely associated with each other, as reflected by their close association to HbA1c. Because these ratios are so simple but potent indicators, they should become part of the regular diabetes management in an attempt to maximize early intervention, make some guidance on

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

intervention, and eventually lessen the burden of cardiovascular disease.

6. Gender, Age, and Ethnic Differences:

Interaction of HbA1c and lipid variables in diabetic patients with type 2 diabetes mellitus changes strikingly with age, gender, and ethnicity.

These demographic variables have indirect effects on all of the pathophysiological processes of dyslipidaemia, insulin sensitivity, and lipid metabolism, and therefore on associated cardiovascular risk and response to treatment. Sexual variations in hormone levels including the decline of oestrogen in the post-menopausal women have been demonstrated to influence the lipid profile. Oestrogens previously cause lipid-lowering effects; thus, postmenopausal women have a tendency of having high total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C). This hormonal change highly increases its risk of heightened atherosclerosis and cardiovascular disease (CVD) in older diabetic females. Also, during the postmenopausal stage, women are able to exhibit changing LDL particle size and acceleration of small dense LDL, which enhance cardiovascular risk. However, greater correlations between triglycerides (TG) and HbA1c may hold true in the case of younger people, adolescents, and those less than 40 years. This is commonly associated to inactive lifestyles, high level of visceral obesity and an increased probability of insulin resistance among them. These individuals, even at an early disease phase of diabetes, possess an atherogenic array of lipids because of ill glycaemic regulation and it also leads to reduced HDL-C levels, poor lipolysis and over-secretion of VLDL by the liver.

Ethnic heterogeneity is also important in the modulation of the relationship that exists between lipid profiles and HbA1c. They depend, not only on the fluctuations in insulin responsiveness, but also in the lipoprotein metabolism, as well as on genetic, dietary, and lifestyle issues.

For instance:

• South Asians have been found to have high triglycerides and low HDL-C even at comparatively low values of HbA1c. This "dyslipidaemia with normal glycaemia" phenotype makes such progressively minor elevations in blood glucose put South Asians at strikingly high risk of CVD. Both the aberrant HDL and normal tiny, dense LDL particles contribute to further increase in atherogenicity. Middle Eastern population has particularly been affected by the insulin resistance brought about by obesity. Without treatment, the high prevalence of central obesity in these groups further leads to severe disturbances in lipid and glycaemic values, which may be harmful to the cardiovascular system.

Relative to the other ethnic communities, the binding of HbA1c and LDL-C seems to be higher within the African communities. It may be partly related to genetic variations in the expression or activity of LDL receptors that are, in turn, determinants of LDL clearance and plasma concentrations. Additionally, the inflammatory marker patterns and the fat distribution patterns that are typical of these populations may exert an add-on effect on the lipid metabolism.

These results show the significance of targeting ethnically responsive, and precision-based treatment of T2DM patients with dyslipidaemia. Due to the confounding and variant influence of age, sex, and ethnicity on lipid-and glucose homeostasis, a blanket solution is incomplete. When interpreting the lipid profile of diabetic patients, physicians must consider these population modifiers and adjust the treatment goals in consideration of the same.

To conclude, since the influence of the age, gender, and ethnicity are demographic factors that affect the interaction of HbA1c and lipids more, these factors have to be taken into account carefully in the process of treating diabetes. The differences may be exploited to guide the population-based lipid-lowering drugs development, optimize cardiovascular effects between ethnically-diverse groups of T2DM patients, and modulate risk prediction.

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

Table 3: Population-Specific Trends in Lipid Profile Alterations Among Individuals with Type 2 Diabetes Mellitus

Population Group	Typical Trend
South Asians	High TG and Low HDL-C even at modest HbA1c level.
Middle Eastern	Obesity-linked insulin resistance affect all lipid markers.
Africans	Stronger HbA1c-LDL-C correlation due to genetic predispositions.
Postmenopausal Women	Higher LDL-C and TC due to hormone changes.

7. HbA1c as a Predictor of Cardiovascular Risk:

Cardiovascular risk is increased both by dyslipidaemia and elevated HbA1c, independently; in combination, however, it is significantly higher. A synergistic burden to atherogenic has already been shown where high TG and the LDL-C frequently co-occur with the elevation of HbA1c > 8 per cent.

According to the research by Yadav et al. (2019), it was revealed that patients with diabetes type 2 and HbA1c >8 percent and LDL-C >130 mg/DL were more prone to develop a myocardial infarction within the five years of study than patients with favorable metabolic conditions by three times.

Risk-stratification calculators (e.g., ASCVD calculators) have more predictive power when cholesterol and HbA1c are included.In addition to this, frequent HbA1c measures can make implicit hints that the patient requires lipid profiling or a transfer to a statin.

8. Clinical and Therapeutic Implications:

The association between lipid profiles and HbA1c has many treatment benefits.

• Early detection: An increased HbA1c presents the possibility of being screened with dyslipidaemia.

• Monitoring response: Rising levels of lipid have been found to be associated with rising levels of HbA1c.

* Risk stratification: Risk stratification with dyslipidaemia and higher HbA1c should implement drastic pharmacological and lifestyle interventions.

• Combined therapy: The medications that increase lipid and glycaemic level include SGLT2 inhibitors, pioglitazone and GLP-1 agonist.

An evaluation and regulation of cholesterol and HbA1c at the same time in clinical practice benefit patients and reduce the budget of medicine.

9. Existing Research Limitations:

Although the statistics are very constant, some limitations are present:

Since most of the studies are cross-sectional, causal inference is restricted.

Food, exercise and use of drugs are some of the uncontrolled confounding factors, which are more often than not present.

• Variation in the levels and measures of HbA1c and cholesterol

• Hemoglobinopathies or anaemia impact on the value of HbA1c

It is recommended in future that longitudinal, multicentre studies preferably based on standardised procedures be conducted. More so, the use of metabolomics investigations and genetic mapping will identify concealed modulators of HbA1c-lipid affiliations.

Summary Table:

Lipid Component	Correlation with HbA1c	Direction	Strength
Total Cholesterol (TC)	Yes	Positive	Moderate
LDL- C	Yes	Positive	Moderate-Strong
HDL-C	Yes	Negative	Moderate

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

The ratios of triglycerides (TG) are higher and positive. It is one of the most important and powerful one. This literature review and biological plausibility reported a close association between HbA1c and abnormal lipid profile in Type 2 Diabetes Mellitus. The association between hyperglycaemia and dyslipidaemia is shown by hormonal disorders, insulin resistance as well as oxidative damage. HbA1c is closely correlated with triglycerides and atherogenic ratios, which are two of the lipid markers. Once clinicians become aware of this association, then they may improve cardiovascular outcomes in diabetes patients by mobilizing an integrated risk assessment and management approach.

Discussion:

Key Finding:

This review demonstrates that in those with Type 2 Diabetes Mellitus (T2DM), there is a consistent relationship between glycated haemoglobin (HbA1c) values and other lipid profile indicators. Strong positive correlation is found between HbA1c and triglycerides (TG), and atherogenic lipid ratios, i.e., TG/HDL-C and LDL-C/HDL-C. LC-D and TC are moderately positively related and LC-D and TC are negatively related. These associations imply that suboptimal glycaemic control is directly linked to dyslipidaemia that is a major source of increased cardiovascular risk in people with type 2 diabetes.

Contrary to other research:

Other international and regional studies validate the interrelationships explained within this study.

In such a way, the findings of Singh et al. (2022), Alam et al. (2019) confirm the high level of the HbA1c-TG association developed by Kumar et al. (2021) indicating that triglycerides level projects drastically in case of poor glycaemic control. The negative correlation between HbA1c and HDL-C that was supported by the other measures like, age and ethnicity also supports the international data sets that were based on Framingham and INTERHEART studies. These trends confirm and justify the relevance accumulating relationship of HbA1c and lipid.

Clinical Implications:

Such exchanges are more of an impact of oxidative destruction, insulin resistance and dyslipidemia. A higher HbA1c indicates long-lasting hyperglycemia, which elevates lipolysis and enhances synthesis of VLDL in the liver and restricts clearance of lipoproteins. Oxidation and glycation both increase the atherogenic risk of LDL particles at the same time. The HDL-C though becomes nonfunctional and triglyceride loaded; it loses its cardio protective effect. These interconnected processes expresses the fact that patients with diabetes type 2 experience wider lipid profiles when the glycaemic control is at a lower level.

Clinical Implications:

These findings also have considerable clinical implications.

To begin with, it appears that in places with low resources and where complete analysis of lipids seems not viable, HbA1c can be accepted as an alternative marker to test the presence of dyslipidaemia. Second, patients with high HbA1c are advised to have regular screening of abnormal lipids and particularly TG and HDL-C. Third, methods of pharmacological therapy which enhance glycaemic control often enhance lipid makers hence enjoying a two fold advantage. Finally, when both controlling the lipid profile and the HbA1c is ranked, the chances of macrovascular events like coronary heart disease and stroke can also be minimized.

Population differences: The HbA1c-lipid association differs between populations due to dietary, lifestyle and genetic factors. As an illustration, the South Asians will tend to overweigh the effect of hyperglycemia on the lipid metabolism compared to the Western population because of lower base HDL-C and increasing TG.

Besides that, age, and even gender trends exist, and lipid profile abnormalities are worse in postmenopausal women because of changes in hormones. These assumptions provide the evidence that these findings are in support of recommendations in different places and ethnically and demographically sensitive policies in government. Pros and Cons of the Analyzed Study:

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

This review is good since the findings are similar in other studies, among various populations, and in various contexts.

Standardised biochemical tests and large sample sizes were two of the effective approaches which were conducted in the majority of the researches.

However, these had certain limitations. Since a number of the tests were cross-sectional it was more challenging to come up with conclusions relating to causality. Other factors that were not always considered were confounding factors such as dietary habits, physical activities, and medication (statins, insulin). Additionally, a number of studies did not adjust anaemia and hemoglobinopathies that had the potential to weaken the validity of HbA1c. Research Gaps and Future Research: Although it has been determined that there is indeed a correlation between HbA1c and lipid markers, there are still numerous problems. Longitudinal studies should be taken to decipher the chronologic order and that of cause and effect of lipid and glycaemic profile changes.

Moreover, evidence needs to be established on whether an aggressive reduction of HbA1c levels alone have benefits on cardiovascular conditions and lipid levels.

Genetic and metabolomic characterisation could be used to determine subgroups with abnormally high or low correlations and facilitate precision medicine procedures through these. Finally, in the last point, interventional studies combining medication and lifestyle interventions can show the most effective combination care measures.

Conclusion:

Glycated haemoglobin (HbA1c) and markers of lipid profile have been demonstrated to manifest a high clinical association in patients with Type 2 Diabetes Mellitus (T2DM). This review shows the highly mutually supportive relationship between atherogenic lipid disorders, characterised by increased triglycerides (TG), reduced HDL-C, and increased total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C), and de-regulated glycaemic control demonstrated by high HbA1c levels. Among all of them, the lipid ratios and triglycerides, TG/HDL-C and LDL-C/HDL-C linked to HbA1c the most.

Chronic hyperglycemia worsens the pathophysiological mechanisms underpinning these associations, which include mainly insulin resistance, high hepatic synthesis of fat, and ineffective metabolism of lipoproteins. Such changes in lipids majorly contribute to the high cardiovascular risk of T2DM patients. It is noted in the article as well that HbA1c plays a significant role as a surrogate, index of dyslipidaemia and in assessing glycaemic control, especially in resource-constrained environments. It has been shown convincingly that burden of the macrovascular caused effect can be reduced greatly with an all-together approach of managing the hyperglycemia and cholesterol at the same time. Differences in populations in the association between HbA1c and lipid warrant the importance of specific populations with respect to patient care and population health programs. The age, gender and ethnicity diversities should be considered during the formulation of medical standards, diagnostic and treatment schedules. More larger-scale, longitudinal and interventional studies are needed to determine the efficacy of multiple therapeutic modalities, and help explain causality better. To create precision medicine initiatives, the future research should consider metabolic, genetic and lifestyle information. Finally, the complex nature of the association between the lipid profile and HbA1c is imperative as far as risk quantification, early diagnosis and management of people with Type 2 Diabetes Mellitus is concerned. Management of glycaemic and lipid should be an important constituent in the care of diabetes in a bid to reduce cardiovascular morbidity and mortality.

REFERENCE:

American Diabetes Association: Diabetes mellitus diagnosis and categorisation. S81–S90 in Diabetes Care, 37(Suppl 1), 2014.

The World Health Organisation. Worldwide diabetes report. WHO, Geneva, 2016.

Cooper ME, Forbes JM. Diabetes problems' mechanisms. (2013) Physiol Rev. 93(1):137–188.

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

Hu FB. Diet, lifestyle, and genetics in the globalisation of diabetes. Diabetes Care, 34(6), 2011, 1249–1257.

The International Federation of Diabetes. IDF Diabetes Atlas. Brussels: IDF, 2021, 10th ed.

Shera AS, Qureshi H, Fawwad A, and Baset A. The Second National Diabetes Survey of Pakistan (NDSP), conducted from 2016 to 2017, examined the prevalence of diabetes, pre-diabetes, and related risk factors.

Shoelson SE, Donath MY. Diabetes type 2 is an inflammatory condition. Immunol. Nat Rev.. 2011;11(2):98–107.

Beckman JA, Creager MA, Libby P. Epidemiology, pathophysiology, and management of atherosclerosis and diabetes. 2002; 287(19):2570–2581; JAMA. Turgeon H, Regan S, Nathan DM. Glycated haemoglobin levels and mean glucose levels over time are related. Diabetologia, 50(11), 2239–2244, 2007.

Sakharkar MK, Masood A, Ekhzaimy A, Khan HA, and Sherwani SI. Hemoglobin A1c test significance for diabetic patient diagnosis and prognosis. Biomark Insights, 11:95 104, 2016.

The American Diabetes Association. Diabetes Medical Care Standards—2023.

The American Diabetes Association. Glycaemic goals. 2023;46(Suppl 1):S97–S110; Diabetes Care.

Lorenz RA, Little RR, Goldstein DE, et al. Glycemia tests for diabetes. Diabetes Care, 27(7), 1761-1773, 2004.

Neil HA, Adler AI, Stratton IM, et al. Glycaemia and type 2 diabetes's microvascular and macrovascular problems are related. 2000; 321(7258):405–412 in BMJ.

Berkenblit G, Marinopoulos S, Selvin E, et al. Meta-analysis: Cardiovascular disease with glycosylated haemoglobin in diabetes mellitus. 141(6), Ann Intern Med. 2004:421–431.

Kilpatrick ES, John WG, Smith G, Dhatariya K, English E, and Idris I. A thorough study of the impact of anaemia and erythrocyte index anomalies on HbA1c analysis. Diabetologia, 58(7), 1409–1421, 2015.

Tuomilehto J, Bonora E. The benefits and drawbacks of using A1C to diagnose diabetes. 2011;34(Suppl 2):S184–S190; Diabetes Care.

Diabetes-related dyslipidaemia, Taskinen MR. In 2002, Atheroscler Suppl. 3(1):47–51.

18. Haffner SM. Therapy of dyslipidaemia in diabetic adults. S68–S71 in Diabetes Care, 27(Suppl 1), 2004.

Adels M, Boren J, Olofsson SO, and Taskinen MR. The hallmark of dyslipidaemia in the metabolic syndrome is an excess of VLDL particles. Vascular Biol. Arterioscler Thromb 2008;28(7):1225–1236.

Davidson M, Furberg CD, Brunzell JD, et al. Lipoprotein control in those at risk for cardiometabolic disease. J Am Coll Cardiol. 51(15):1512–1524, 2008.

Chanel WB. The Framingham Study's Findings on Lipids, Diabetes, and Coronary Heart Disease. 1985; 110(5):1100–1107; Am Heart J.

Grudy SM, Merz CN, Cleeman JI, et al. Recent clinical trials' effects on the Adult Treatment Panel III recommendations of the National Cholesterol Education Program. Circulation, 110(2), 2004: 227–239.

Raven GM. Insulin resistance's role in human illness. Diabetes. 37(12):1595-1607 (1988).

Hovingh GK, Rader DJ. 2014;384(9943):618–625; HDL and cardiovascular disease. Lancet.

Amarenco P, Ginsberg HN, Chapman MJ, et al. High-density lipoprotein cholesterol and triglyceride-rich lipoproteins in individuals at high risk of cardiovascular disease. 2011;32(11):1345–1361, Eur Heart J.

Ballantyne C, Stone NJ, Miller M, et al. Cardiovascular illness and triglycerides. 2011; 123(20):2292–2333, Circulation.

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

Brownlee M. A. Unifying Mechanism in the Pathobiology of Diabetic Complications. Diabetes, 54(6), 2005, 1615-1625.

Ozder A. A cross-sectional study of lipid profile anomalies observed in T2DM patients receiving primary care in Turkey. Health Dis. Lipids, 2014, 13:183.

Jahan M, Farah S, Maliha G, et al. Relationship between HbA1c and serum lipid profile in individuals with type 2 diabetes. In 2019, Pak J Med Sci. 35(2):597–600. 30. Adhikari PM, Chowta MN, and Chowta NK. Dyslipidaemia in coronary artery disease and diabetes mellitus. 123–126 in Indian J Clin Biochem. 2008;23(2).

Shah NA, Masoodi SR, Zargar AH, et al. A study from the Indian subcontinent examined the relationship between lipid profile and HbA1c in people with type 2 diabetes. Invest. J Endocrinol 2007; 30(8):597–602.

Puri P, Garg MK, and Kharb S. Assessment of dyslipidaemia in individuals with type 2 diabetes. 2011;59:29–32; J Assoc Physicians India.

Li Y, Gao J, 35. Carter J, et al. A comprehensive cross-sectional study conducted in China examined the prevalence of dyslipidaemia in individuals with type 2 diabetes by sex and age. Frontocrinol. 12:622251, 2021.

Rosenblit PD, Handelsman Y, Jellinger PS, et al. Guidelines for the Treatment of Dyslipidaemia and the Prevention of Cardiovascular Disease, American College of Endocrinology and American Association of Clinical Endocrinologists. 2017;23(Suppl 2):1–87;Endocr Pract: