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Correlation between glycated albumin levels (fructose amine), Biochemical markers, and Atherogenic Index in diabetes diagnosis

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ABSTRACT

Diabetes mellitus corresponds to an insulin-resistant metabolic disorder characterized by hyperglycemia; as such, the most common form of this disease is T2DM, which affects more than 95% of patients worldwide. The current study evaluated the potential of fructosamine levels in the short-term assessment of glycemic management in T2DM patients. We included 80 blood samples from diabetic patients, which were divided into two groups: T2DM and diabetic controls. In the T2DM group, BMI was higher with significantly different values of insulin, HbA1c, and HOMA-IR compared to those of the power. The fat levels and atherogenic indexes were higher in the T2DM group. A significant positive correlation between fructosamine and HbA1c % was observed in diabetic patients. HOMA-IR, however, showed extraordinary sensitivity and specificity for predicting glycemic management. There was also resistance with advancing age to diabetes. These findings underscore the role of fructosamine levels and other factors in assessing glycemic control in T2DM patients.

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1. INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both. Proper diagnosis and monitoring of the patient are essential for effective diabetes management and the prevention of complications. Glycated albumin, fructosamine, biochemical indicators, and the atherogenic index are generally helpful in diagnosing and following up diabetic patients. The following paper will discuss the inter-relationship between the indicators and how this may be used in diabetes diagnosis [1]-[2]. Glycated albumin reflects short-term glycemic control over 2-3 weeks, making it a useful marker for monitoring changes in glucose levels more rapidly than HbA1c. Studies have shown that glycated albumin is a reliable marker for assessing glycemic control, particularly in conditions where HbA1c may be unreliable, such as anemia or hemoglobinopathies [3]-[4]. The correlation between glycated albumin and diabetes complications, including retinopathy and nephropathy, has been documented, suggesting its potential utility in risk stratification [5]. Glycated albumin measurements in biochemical markers and atherogenic indices for the diagnosis and management of diabetes mellitus, especially T2DM. Glycated albumin, also commonly referred to as fructosamine, estimates average blood glucose over the past two to three weeks and is one component of short-term glycemic control. This makes it a valuable tool for assessing the effectiveness of diabetes management strategies, mainly when rapid changes in blood glucose levels occur, such as during medication adjustments or in pregnancy-related diabetes [6]. Fasting plasma glucose, HbA1c, and C-peptide are typically measured to diagnose diabetes. Indeed, HbA1c remains the gold standard for long-

term glycemic control, reflecting average blood glucose over about 3 months. However, in some populations, the limitations described above require supplementary markers, such as glycated albumin. This can be achieved by combining several biochemical markers to improve diagnostic accuracy and better represent an individual's glycemic status [7]-[8].

The atherogenic index, which is the ratio between the triglycerides and high-density lipoprotein cholesterol, is an important indicator of cardiovascular risk, especially in people with diabetes. It has been documented that individuals with a high atherogenic index face a higher risk of atherosclerosis and various cardiovascular events[9,10]. The atherogenic index has been firmly found to be associated with insulin resistance, a characteristic common feature of type 2 diabetes [11]. This relationship places an atherogenic index alongside traditional glycemic markers in assessing cardiovascular risk [12]. Recent research has explored the relationship between glycated albumin, biochemical indicators, and the atherogenic index in the context of diabetes diagnosis. For example, an investigation conducted by[13] revealed a significant association between glycated albumin levels and the atherogenic index among individuals with type 2 diabetes, emphasizing its importance in evaluating cardiovascular risk. Additionally, another study illustrated that the integration of glycated albumin with conventional biochemical markers enhanced the forecasting of complications associated with diabetes [14]

2. METHOD

A total of 120 blood samples were collected within three months from December 1, 2023, to February 30, 2024. Blood samples used in this research were derived from patients who have been admitted to Baquba Teaching Hospital, Diyala Governorate. Blood samples of eighty diabetic patients were collected after being diagnosed by the specialist physician at Baquba Teaching Hospital, Diyala Governorate. The eighty samples were divided into two different groups: Group A, the irregular (bad control) patients, contains sixty subjects who are further divided into twenty-four males and thirty-six females, whose ages range between thirty-five and seventy-seven years. On the other hand, Group B, that of the regular good control patients, contains twenty patients, divided into eleven males and nine females between the ages of thirty-four and seventy-five years. An additional forty samples from the healthy group, involving fourteen males and twenty-six females whose age bracket was between thirty-one and forty-nine years, were used as a control group in this study. The control group was not subjected to any chronic or acute disease during the time when the sample was withdrawn.

Blood was withdrawn from the venous system using plastic medical syringes that aspirated 5 milliliters. The blood was initially put in EDTA tubes for HBA1C test and then transferred into gelatin tubes. Serum separation was done by spinning the sample in the centrifuge for ten minutes at 3000 revolutions per minute. Two equal volumes, 250 microliters of serum, were then distributed into small tubes. The first half is used for blood tests, and the second half is stored at 20 ◦C for the examination of Fasting insulin (FSI) and Fructoseamine (FTA).

BMI has been calculated according to a specific formula which includes weight divided by the square of height as the flaunting equation the weight status divided according to the value of BMI

IR can be estimated by the HOMA-IR equation: [glucose × fasting insulin] / 405. Higher IR values mean the role of insulin resistance is significant.

HOMA-IR= [glucose(mg/dl) x fasting insulin(µIU /ml)] /405

The calculation was derived from molar ratio of the logarithm of triglyceride to high-density lipoprotein. AIP=log(TG/HDL-C)

A value less than 0.11 is related to a low risk of CVD; a value within the 0.11 to 0.21 range reflects an intermediate risk for CVD; and any values above 0.21 are related to increased or high risks for CVD.

Statistical analysis: All statistical analyses were done using SPSS version 25.0 and GraphPad Prism version 6. The type of analytical approach used depended on the type of data being analyzed. A t-test was used in comparing two groups of data, depending on whether such data showed a normal or skewed distribution. One-way ANOVA or its non-parametric test alternative was used when there were comparisons to be made for three or more groups. P values of < 0.05 were considered to be of statistical significance and are presented in tables as * = $p<0.05$, = $p<0.01$, * = $p< 0.001$.

3. RESULTS AND DISCUSSION

This study employed the HbA1c screening test to identify the cohort of individuals who were obese and shown a heightened susceptibility to insulin resistance and diabetes. Subsequently, the participants were divided into two cohorts based on their HbA1c levels. The average age of the control group was 31.66 years with a standard deviation of 9.5 years. The age range of the control group spanned from 20 to 55 years, with 20 being the youngest age observed. Table 1 displays the mean age (45.15±8.11 years) and age range (20-55 years) of the T2DM Patients group. Based on the statistical analysis conducted on the data, as presented in Table 1, it was observed that the average age of individuals in the Diabetic group was significantly higher compared to that of those in the non-diabetic group ($P < 0.05$).

Table 1: The present study examines the age distribution among patients in two distinct groups: those classified as obesity and those classified as non-obese.

Studied groups	Ages	Number	Mean±SD	p-value
T2DM Patients 1	Age >40	32 (53%)	52.13±5.43	P < 0.0001
	Age <40	28(47%)	39.11±4.99	t= 5.13
	Total	60(100%)	45.15±8.11	
Control 2	Age >40	11 (18.3%)	50.18±2.46	P < 0.0001
	Age <40	49(81.7%)	31.66 ±9.5	t =6.32
	Total	60 (100%)	30.15± 7.3	
		Chi-sequre 18.99 p-value < 0.001		

The study showed that there were clear and obvious changes in fat levels when comparing the study groups as shown in table 2 , the mean and SD of total cholesterol in type 2 of DM was (184.29±44.00) and in controlled type2 was (168.48± 23.83) while in control group was (122.58± 19.06) ,and therefore the p-value between studied group shown in table 3 there's result no significant between group 1 and 2 (-value = 0.072) while between 1and 3 (p-value<0.001). in comparison for TG in studied groups , the mean and SD in group 1 (158.3± 52.62) and in group 2 (143.1±36.14) while in controlled group 3 was (89.93±16.58) therefore the significant value for triglyceride in studied groups represented in table 3 . There's result no significant between group 1 and 2 (value = 0.150) while between 1and 3 (p-value<0.001). Also there's significant value for Atherogenic index in studied groups , in group 1 (0.4662±0.1821) , in group 2 (0.365±0.1985) , in controlled group mean and SD (0.214 ±0.1051) and therefore there's result slightly significant between group 1 and 2 (-value = 0.021) while between 1and 3 (p-value<0.001) as shown in table 3.

Table 2: Mean and SD of lipid profile and atherogenic index in diabetic patient with control groups

Groups		T.Cho. mg/dL	TGs mg/dL	HDL. mg/dL	LDL mg/dL	VLDLmg/ dL	AIP
T2DM Patients (1)	Mean	184.29	158.3	54.2	102.2	32.654	0.4662
	SD	44.00	52.62	11.8	33.5	12.920	0.1821
	Median	180.00	160.0	53.0	99.0	32.000	0.4956
T2DM Control (2)	Mean	168.48	143.1	54.8	85.49	28.262	0.3685
	SD	23.83	36.14	13.2	19.70	7.354	0.1985
	Median	168.00	144.0	53.0	80.00	28.000	0.3705
Controls Group (3)	Mean	122.58	89.93	51.3	59.88	17.985	0.214
	SD	19.06	16.58	7.47	15.06	3.317	0.1051
	Median	120.00	88.50	54.0	61.80	17.700	0.2414
Total	Mean	160.95	132.66	53.38	86.18	26.996	0.3734
	SD	43.97	51.11	10.88	32.30	11.726	0.1910
	Median	153.50	120.00	54.00	78.20	24.000	0.3596

Table 3: mean difference between lipid profile and atherogenic index in diabetic patients with control groups.

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	P-Value
T. Cho. mg/dL	1	2	15.81	8.72	0.072
		3	61.71*	7.03	0.000
	2	1	-15.81	8.72	0.072
		3	45.90*	9.25	0.000
TGs mg/dL	1	2	15.12	10.43	0.150
		3	68.39*	8.42	0.000
	2	1	-15.12	10.43	0.150
		3	53.27*	11.04	0.000
HDL.c mg/dL	1	2	-0.60	2.76	0.828
		3	2.93	2.23	0.191
	2	1	0.603	2.76	0.828
		3	3.53	2.93	0.230
LDL.c mg/dL	1	2	16.73*	6.86	0.016
		3	42.32*	5.89	0.000
	2	1	-16.73*	6.86	0.016
		3	25.59*	7.46	0.001
VLDL.c mg/dL	1	2	4.39	2.49	0.080
		3	14.67*	2.00	0.000
	2	1	-4.39	2.49	0.080

		3	10.28*	2.64	0.000
AIP	1	2	0.098*	0.042	0.021
		3	0.22*	0.034	0.000
	2	1	-0.10*	0.042	0.021
		3	0.13*	0.04	0.005

The mean and SD of urea in the T2DM patients group 1 were 30.28±9.94, the mean and SD in group 2 were 33.05 ±8.00, and in the control group, it was 25.40±5.17. The p-value that is considered to have a non-significant value of the urea levels in the studied group is represented in Table 5, with a p-value of 0.192 between groups 1 and 2, and between 1 vs. 3 being 0.06. The mean ± SD (according to creatinine levels in the studied groups) in T2DM patients was 0.81±0.19, in T2DM Control it was 0.92±0.28, and in the control group, it was 0.71±0.13. The significant values are presented in Table 5, which shows a mean difference between group 1 and group 2 to be (-0.1085*) with a p-value of 0.031, and a mean difference between group 1 and group 3 to be 0.0943* with a p-value of 0.04. Albumin levels are also represented in Table 4, with the mean and SD of T2DM patients, being 1, 4.16±0.19, in group 2 T2DM Control, 4.21±0.26, also in controlled group 3, 4.14±0.15; no significant difference is shown between the steadied groups for the albumin levels, as is shown in table 5. The mean, SD of group 1, in comparison, are 4.53 ±1.073, for studied groups of glycated albumin, compared with T2DM Control, group 2, 4.20±0.39, and the low level of GA as compared with group 1 and 2 is 2.54±0.77. So, no significant difference exists between groups 1 and 2 since the mean difference is = .33513 and p-value = 0. 142. In contrast, a highly significant difference exists between groups 1 and 3, since the mean difference = 1.98785 and the p-value <0.0001. This result is represented in Table 5.

Table 4 : Mean and SD of (urea ,creatnine , Albumin and GA) in diabetic patient with control groups

Groups		Urea mg/dL	Creatinine mg/dL	Albumin g/dL	GA mmol/L
T2DM Patients (1)	Mean	30.28	0.81	4.16	4.53
	SD	9.94	0.19	0.19	1.073
	Median	28.00	0.80	4.16	4.43
T2DM Control (2)	Mean	33.05	0.92	4.21	4.20
	SD	8.00	0.28	0.26	0.39
	Median	33.0	1.00	4.20	4.20
Controls Group (3)	Mean	25.40	0.71	4.14	2.54
	SD	5.17	0.13	0.15	0.77
	Median	24.00	0.70	4.15	2.86
Total	Mean	29.14	0.79	4.16	3.81
	SD	8.70	0.21	0.19	1.27
	Median	27.75	0.80	4.16	3.85

Table 5: mean difference and significant value between (urea, creatinine, albumin and GA) in diabetic patients with control groups.

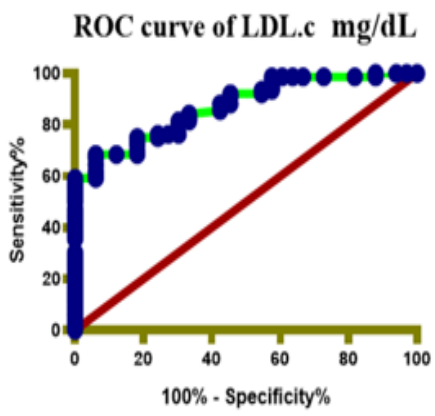
Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	P-Value
Urea mg/dL	1	2	-2.768	2.11	0.192
		3	4.880	1.70	0.06
	2	1	2.768	2.11	0.192
		3	7.648	2.24	0.059
Creatinine mg/dL	1	2	-.1085*	0.05	0.031
		3	.0943*	0.04	0.040
	2	1	0.108*	0.05	0.031
		3	0.203*	0.05	0.000
Albumin g/dL	1	2	-.056	0.05	0.253
		3	0.013	0.04	0.738
	2	1	0.056	0.05	0.253
		3	0.069	0.05	0.184
GA mmol/L	1	2	.33513	.22662	0.142
		3	1.98785*	.18266	0.000
	2	1	-.33513	.22662	0.142
		3	1.65271*	.24033	0.000

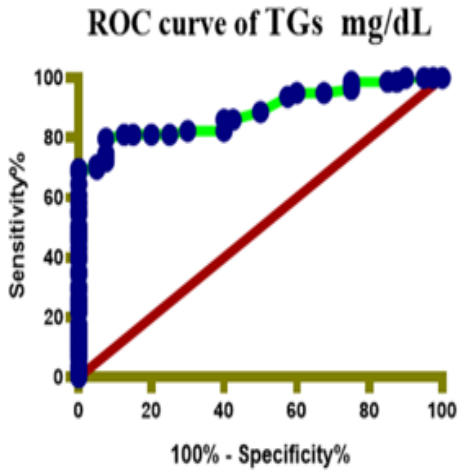
Table 6 and Figure 1. shows the sensitivity and specificity of lipid profile, in particular, total cholesterol, having an area under the curve of 0.918, a sensitivity of 82.50%, and a specificity of 80.00%. Triglycerides have an area under the curve of 0.8873, with a sensitivity of 81.01% and a specificity of 80.00%. On the other hand, albumin, urea, and creatinine have a quite low sensitivity and specificity, with albumin

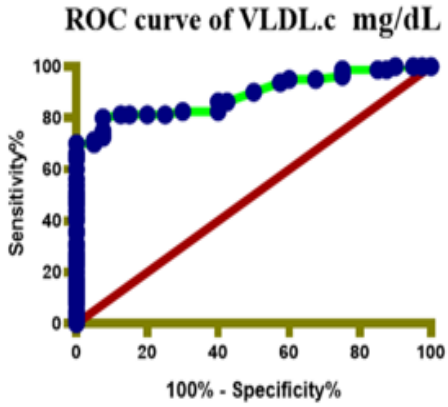
having an area under the curve of 0.538, a sensitivity of 53.75%, and a specificity of 50.00%; urea having an area under the curve of 0.6677, a sensitivity of 61.25%, and a specificity of 62.50%; and creatinine having an area under the curve of 0.6598, with a sensitivity of 82.50% and a specificity of 58.75%, respectively. It has a high percentage sensitivity and specificity in glycated albumin, as shown in Table 6, with an area under the curve of 0.9717, percentage sensitivity of 88.75, and percentage specificity of 87.50.

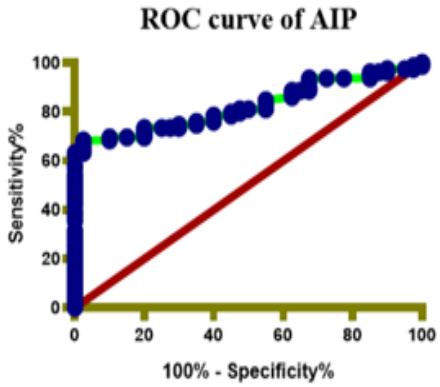
Table 6. Roc curve analysis for parameters in diabetic patients with control groups.

Parameter	AUC	Positive if COV	Sensitivity%	Specificity%	Likelihood Ratio
T. Cho. mg/dL	0.9180	> 145.5	82.50	80.00	4.125
TGs mg/dL	0.8873	> 103.5	81.01	80.00	4.051
HDL.c mg/dL	0.5384	> 53.50	47.50	40.00	0.7917
LDL.c mg/dL	0.8714	> 72.30	76.32	75.76	3.148
VLDL.c mg/dL	0.8897	> 20.70	81.25	80.00	4.063
AIP	0.8236	> 0.33	73.42	72.50	2.670
Albumin g/dL	0.5384	> 4.150	53.75	50.00	1.075
Creatinine mg/dL	0.6598	> 0.75	58.75	62.50	1.567
Urea mg/dL	0.6677	> 26.50	61.25	62.50	1.633
GA mmol/L 0.9717	> 3.400	88.75	87.50	7.100	









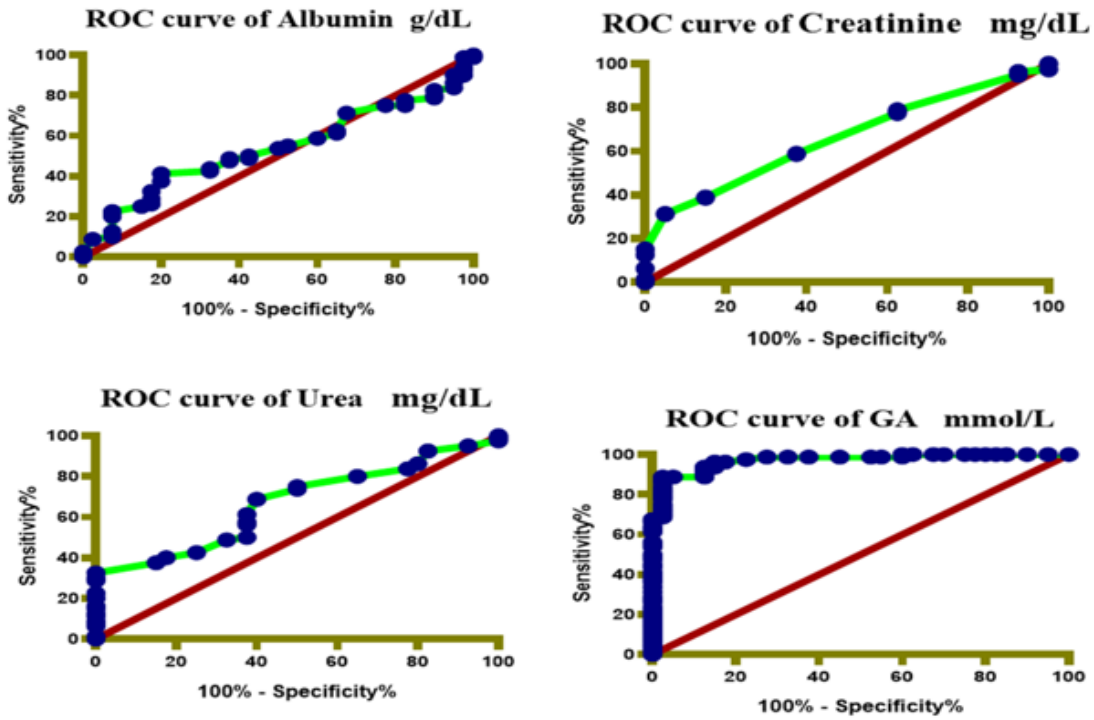


Figure 1. Roc curve analysis for parameters in diabetic patients with control groups

Discussion:

In this study, findings agree with the work from Gluba-Brzózka, A et al 2022 [15]. There it was stated that after the onset of dyslipidemia, in patients with T2D, due to enhanced release of FFA from adipose tissue as result of increased lipolysis, more FFA is being transported to the liver. With the increased metabolism of free fatty acids, the levels of liver TG increase, as does the synthesis of VLDL. It also instigates the development of hypertriglyceridemia through the inhibition of activity of lipoprotein lipase in the skeletal muscle and adipose tissue. Further, the elevation of VLDL in the liver can suppress chylomicron lipolysis, exacerbating a condition of hypertriglyceridemia. Also, this finding was in line with the study by Sunil, B., & Ashraf, A. P. (2020) [16], which is generally known as high blood lipids. Its triglyceride is derived from very low-density lipoprotein (VLDL), whereas its high-density lipoprotein is substituted by cholesteryl esters through the action of the cholesteryl ester transport protein. This process then results in the formation of LDL and HDL particles enriched in triglycerides. In the next step, hepatic lipase hydrolyzes TG in HDL and LDL to create dense and small particles of both types of lipoproteins. Park, J. E., et al 2022. [17]

Fructose amine has a potential value as a diagnostic tool for diabetes, gaining advantages over traditional methods of HbA1c and fasting blood glucose assessments. GA reflects the average blood glucose levels over the previous two to four weeks, thus being a more immediate indicator of glycemic control than HbA1c, which refers to the glucose levels over a period of about two to three months. This characteristic makes GA particularly useful in situations in which rapid changes in glycemic status need to be monitored, e.g., pregnancy or on change of diabetes medications American Diabetes Association. (2023) [18]. One of the major advantages of glycemic assessment is its reliability among certain populations where, for some reason, HbA1c cannot give appropriate results. For instance, in conditions like anemia and hemoglobinopathies, which are associated with red blood cell turnover, HbA1c readings are, at times, misleading in their information. Since GA is not affected by such conditions, this makes it a more valid measure of glycemic control in these patients. GA has also been shown to be a better marker for glycemic control in patients on hemodialysis, in whom HbA1c may be artifactually low due to shortened lifetimes of red blood cells Nathan, D et al 2014 [19].

Since it has the ability to differentiate between diabetic and nondiabetic persons, GA is a useful tool in screening and early diagnosis of this disease. There are, however some problems associated with the use of GA. First, there is the likelihood of variation in diagnostic criteria between groups or studies due to the lack of agreed-upon threshold values for diabetes. Other than albumin metabolism and liver function, several other factors may influence the readings for GA levels and therefore the reliability of results obtained. Nevertheless, the promise in the diagnostic use of GA remains very high in view of the above. This test is an extremely useful augmentation to the diagnostic toolset for treating diabetes because it can provide a more rapid read on glycemic control, and because it is applicable across varied clinical circumstances. GA will only continue to

increase in importance as a strategy in treating this disease as future studies further define its use and determine standard procedures for its administration. In the second study, conducted in the Chinese population, the sensitivity and specificity of GA as a diagnostic tool were 73.3% and 80.1%, correspondingly. The study authors determined that the use of cut-off values for both ruling out and diagnosis of diabetes significantly enhanced the sensitivity at 83.3% versus 98.2% for specificity. For example, Shin, A., Connolly, S., & Kabytaev, K. (2023) [20]. They reached the conclusion that simultaneous measurement of FPG and serum GA was the best method for diabetes detection, wherein the cutoff values for FPG and GA would be 6.1 mmol/L and 17.1%, respectively. However, this was applicable to individuals already at a high risk of developing diabetes—those whose fasting plasma glucose levels were 7.8 mmol/L or higher, or those who had a family history of diabetes, or with FPG values of 6.1 mmol/L or higher Matsumoto, S., Shimoda, M., & Nakanishi, S. (2021) [21]. In the present research, participants were recruited from the local population. One of the main directions in the studies related to heart risks in the conditions of diabetes and metabolic syndrome is the interrelation of this index with the fructosamine level Wang, Y., etal. (2020) [22] . It is well documented that the log ratio of triglycerides to high-density lipoprotein cholesterol, the atherogenic index of plasma, is an important indicator of risk for cardiovascular disease. At the same time, fructosamine expresses the average blood glucose levels during a period of two to three weeks before the test and corresponds to the level of glycated serum proteins. These two metrics are important in light of metabolic health and possible risks of cardiovascular health-Kim, K. et al, (2020). [23].

Thus, an increased atherogenic index is related to an increase in serum fructosamine. For example, take the study that aimed to determine the relationship between serum fructosamine and selected characteristics on a cohort basis. In the results obtained, it was noted that serum fructosamine correlated positively with age, total cholesterol, fasting blood sugar, total protein, triglycerides, and total cholesterol to HDL-C ratio, as well as with the Atherogenic Index of Plasma Rashid, I., & Kataria, A. (2020) [24]. A higher fructosamina level therefore reflects poor glycemic control and is associated with an increased risk of cardiovascular disease, mediated at least in part by an atherogenic lipid profile. The metabolic defects underlying fructosamine and AIP explain their association. Indeed, it is well-documented that the dyslipidemia—defined as elevated triglycerides and decreased HDL-C—which raises AIP is frequently associated with poor glycemic management. Atherosclerosis is a critical event in the evolution of cardiovascular disease, and it is this dyslipidemia that, to a certain degree, initiates things. Thus, the relationship of glucose and lipid metabolism is underlined in this connection of the AIP to fructosamine as regards cardiovascular risk Lee, S. H., Kim, J. H., & Lee, Y. J. (2019) [25].. Other studies looked into whether treatment with effects on both the fructosamines and the atherogenic index could affect the latter. One such study concluded that supplementation of type 2 diabetics with chromium picolinate and biotin may have the effect of reducing their plasma atherogenic index.This study, which concentrated primarily on AIP, also demonstrated changes in fructosamine levels that helped to explain, through improved glycemic control, how to improve the lipid profile and reduce cardiovascular risk Chen, Y., Jin, J., & Zhang, X. (2021) [26].
Not only has that, but a combined measure of these two endpoints further supported the need for comprehensive metabolic screening in clinical practice. Measuring AIP, along with measuring fructosamine, cannot only estimate the metabolic status but also the cardiovascular risk of patients, thus directing more focused intervention in lifestyle, diet, or medication treatment for optimal glycemic control and lipid profile. The positive association reported between fructosamine and the atherogenic index is actually a result of complicated interaction of glucose and lipid metabolic pathways in the process of assessment of cardiovascular risk Patel, R. S., Goyal, A., & Patel, J. (2020)[27]. Both high AIP and elevated levels of fructosamine indicate poor glycemic control and an atherogenic lipids profile. This link has to be realized to reduce risk for cardiovascular disease in people with diabetes and metabolic disorders appropriately. Further research in the area is being conducted for the better realization of the mechanisms linking these parameters and to devise integrated methodologies for the promotion of better metabolic and cardiovascular health Singh, K., & Singh, P. (2021) [28].

In patients with such features, there is the need to determine fructosamine, urea, and creatinine levels. There is evidence that there is some relation between fructosamine and blood creatinine and urea levels. That is to say, in the event of any disturbance in the metabolism of proteins and glycation, there might be an increased level of serum fructosamine, which is a sign of renal function disturbances, as evidenced by an increased level of creatinine and urea in the serum. One study revealed that fructosamine correlated positively with total and serum creatinine cholesterol and inversely with HDL cholesterol. Since high levels of fructosamine merely indicate poor glycemic control, it is only expected that they would be associated with renal failure. These interactions have not at all insignificant implications clinically. Similar to urea and creatinine, fructosamine might give a better view of renal function and glycemic control in patients who have chronic renal illness Smith, J. R., & Johnson, L. M. (2023) [29].

Because high blood sugar can promote further kidney damage, speeding up the disease process, considerations of the two conditions should go in tandem. By taking account of all these signals taken together, physicians are better positioned to devise individual treatment plans that tailor the clinical needs of the patient and generate greater outcomes, according Garcia, A., & Patel, K. (2022)[30].The interrelation of these measures also reflects how care is best integrated. For instance, the maintenance of normal blood glucose levels through proper diabetes management is an important measure of preventing complications of the disease and protecting kidney function. Thus, the pharmaceutical and lifestyle therapies might improve renal health through improvement in glucose management.On the other hand, renal failure may be treated with dialysis, dietary restriction, and medicine, all of which can have the effect of better glucose control. Since fructosamine, urea, and creatinine interact to some great degree during metabolic diseases on the basis of renal function and management of glycemia, there is an obvious relationship between these two processes. A clearer understanding of the interrelationships between these markers could lead to better management of diabetes and CKD. Further research into these relationships will improve our understanding of the aetiologies of disease and the effectiveness of conventional diagnostic and treatment methods. Ha, M. et al 2024 stipulate that incorporating these markers in clinical practice would raise the level of care for patients with diabetes and CKD [31].

4. CONCLUSION

This study demonstrates that fructosamine is a reliable short-term indicator of glycemic control in patients with diabetes, while urea and creatinine levels remained within normal ranges and showed no significant changes. This suggests that elevated fructosamine in the studied cohort is primarily linked to impaired glucose regulation rather than overt renal dysfunction. These findings highlight the clinical value of fructosamine as a complementary marker, particularly when HbA1c may be influenced by factors affecting red blood cell turnover. Future research involving patients with varying stages of renal impairment may further clarify the interaction between fructosamine and renal biomarkers and enhance its clinical utility in diabetes management.

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