MODERN MEDICINE AND PRACTICE
https://inovatus.es/index.php/ejmmp

EUROPEAN JOURNAL OF MODERN MEDICINE AND PRACTICE
Vol. 4 No. 6 (Jun - 2024) EJMMP ISSN: 2795-921X

ANEMIA ASSESSMENT IN IRAQI PATIENTS WITH TYPE II DIABETES: A CASE-CONTROL INVESTIGATION

Muthanna C. Urabee, Mohammmed I. Sultan
Quality Assurance & Performance Evaluation Department, Mustansiriyah University, Baghdad, Iraq

Ahmed H. Sadiq
Environment Research Center, University of Technology, Baghdad, Iraq

Roaa M. Kadim
Department of Chemistry, College of Science, Al-Mustansiriyah University, Baghdad, Iraq

Abstract:

Introduction: Diabetes mellitus encompasses a diverse range of chronic conditions marked by increased levels of blood sugar. When an individual with diabetes also experiences anemia, it can substantially impact their quality of life and is related to the worsening of their condition.

Method: The study involved an overall of 80 samples, which were divided into two groups: one including patients and the other serving as controls. Definitely, the patient group involved 40 individuals identified with diabetes, while the control group involved of healthy individuals aged between 30 and 58 years.

Results: The results indicated that glycated haemoglobin (HbA1C) levels in patients were significantly advanced ($p< 0.01$) than in controls. The results also exposed a significant increase in fasting blood sugar (FBS) in Type II Diabetes patients as related to the control evaluations.

Conclusion: In conclusion, as related to the general population, anemia is a recurrent remark among Type II Diabetes patients. On this evidence, we propose that routine hematological testing, as well as blood glucose levels, be made necessary in diabetic outpatient clinics in order to mark the best therapeutic approvals for treating anemia in type II diabetes mellitus.

Keywords: Type II Diabetes mellitus, Anemia, glycated hemoglobin (HbA1C), fast blood sugar (FBS).

Introduction

Diabetes mellitus (DM) is a diverse set of chronic diseases characterised by high blood glucose levels (hyperglycemia) caused by inadequate insulin production (in type I diabetes), insulin resistance (in type II diabetes), or both. Inadequate production or action of insulin generated by the pancreas within the body. The most common symptoms are thirst, hunger, emaciation, and weakness, which can eventually lead to a coma [1].

Between 2000 and 2030, the number of persons with type II diabetes is predicted to more than double [2]. Diabetes incidence has grown in recent years due to a combination of population expansion, population ageing, and higher rates of obesity as urbanization and commercialization sweep the world [3]. It is

estimated that 382 million individuals worldwide have diabetes, with around 46% of cases going untreated [4].

Type II diabetes represents greater than 90% of all confirmed diabetes cases global. While the condition has usually not been encountered in more youthful people, this seems to be changing. Increased formative years obesity prices are main to a upward thrust in the occurrence of kind II diabetes in younger people [5]. Because of the epidemic's heredity and a loss of affected person training, families and groups had been affected. The ease of availability of excessive-sugar, high-fat, low-price food has fuelled this fashion in lots of rich and growing countries alike [6]. Families and communities have been impacted due to the epidemic's heritability and a loss of patient information. The ease of get right of entry to to excessive-sugar, excessive-fat, low-value food has fostered this fashion in both developed and developing international locations[7].

Anemia has a huge negative impact on a diabetic's best of lifestyles and is related to ailment development and the development of comorbidities which includes weight problems and dyslipidemia, which are strongly linked to the diabetic framework and significantly increase the threat of cardiovascular ailment [8].

Anemia might also cause fatigue, weak spot, pale complexion, and decreased interest tolerance. These signs would possibly get worse the great of lifestyles of people with Type II diabetes [9]. Systemic infection, renal interstitium damage, inhibition of erythropoietin launch, extreme symptomatic autonomic neuropathy causing efferent sympathetic denervation of the kidney and loss of appropriate erythropoietin, altered iron metabolism, capsules, and hyperglycemia have all been proposed as reasons for the earlier onset of anemia in diabetic patients [10]. In diabetic people, treating anemia may also entail addressing the underlying motives, along with improving glycemic manipulate, controlling renal ailment, and correcting dietary inadequacies. Depending on the severity of the anemia, iron supplements, erythropoietin-stimulating medications, and blood transfusions will also be explored [11].

Patients with type II diabetes are twice as likely as non-diabetics to have anemia [12]. *Bosman et al.* revealed anemia to be a risk factor for cardiovascular and end-stage renal disease in diabetics [13]. The diabetics with low hemoglobin (Hb) levels are at a higher risk of hospitalization and premature death [14]. *Keane and Lyle* shown that diabetics with low hemoglobin (Hb) levels are at a higher risk of hospitalization and premature death [15].

Diabetes patients also have dietary deficits in cyanocobalamin, folate, and iron, which can lead to various kinds of anemia. Metformin may impair cyanocobalamin absorption, leading to vitamin B12 deficient anemia [16]. Because anemia and type II diabetes overlap symptoms such as pale complexion, chest discomfort, numbness or coldness in the extremities, shortness of breath, and headache, anemia goes undiagnosed in the majority of diabetes patients. As a result, it is critical to detect anemia in diabetes individuals [17]. Individual patient features may differ in the association between anemia and Type II diabetes, which can be complicated and multifactorial. Management and therapy should be adapted to each patient's particular needs [18].

The current work aims to determine the level of some diabetic parameters in the sera of type II diabetes patients and healthy individuals. As well as evaluate if patients with type II diabetes suffer Anemia. To this end, the following has been done: The HbA1C and FBS levels are determined in type II diabetes as well as in healthy control subjects. As well as Levels of HB are also determined to evaluate Anemia in patients with type II diabetes and compared with the healthy control subjects.

Materials and methods

Specimen Collection

Each research participant (patient and control) had 10 mL of venous blood taken with plastic disposable syringes. Two milliliters were taken in an EDTA tube and eight milliliters in a gel tube. After collection,

whole blood samples in EDTA tubes were stored in a cooling freezer at 2-4°C. The samples in the gel tubes were centrifuged for 10 minutes at 3000 rpm. The serum that produced was stored at -20 ^{o}C until analysis.

Study Population

The study's participants were separated into two groups: patients and controls. The patient group comprised of 40 diabetic patients (26 females and 14 males, ages 30-58). An expert diagnosed the individuals with diabetes. The control group included 40 healthy people who were age-matched to the sick group (22 females and 18 males).

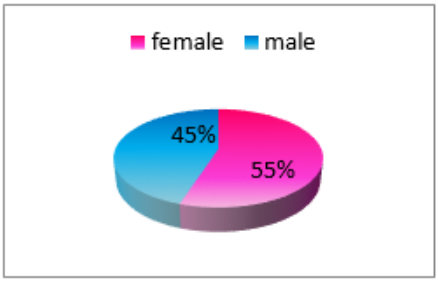


Figure 1: Gender distribution of the control group.

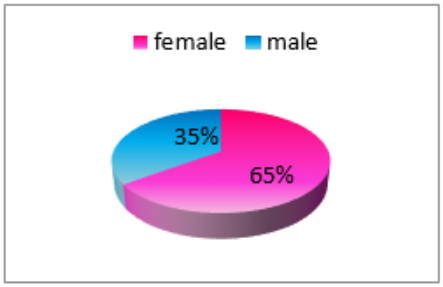


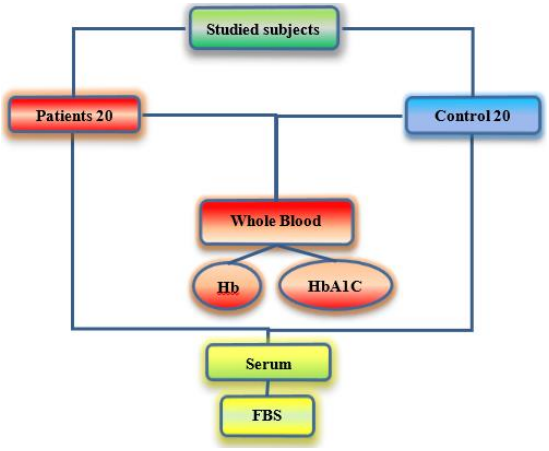
Figure 2: Gender distribution of patients group.

Between January and March 2023, subjects were drawn from patients who visited the Dar Al-Shifaa lab in Baghdad, Iraq. The exclusion criteria were as follows: none of the patients were smokers, alcoholics, or pregnant. Furthermore, none of the individuals had a history of the condition.

Sample Analysis

Levels of glycated hemoglobin (HbA1C) were determined by following the protocol of the Stanbio Laboratory An EKF Diagnostics Co., USA. Determination of fasting blood glucose (FBS) by the colourimetric method according to the protocol supplied by commercially available Randox kits supplied by Randox Laboratories Limited, United Kingdom.

An automatic cell counter is often used to determine hemoglobin levels from a tube of well-mixed EDTA-anticoagulated blood complete to a specified level. All hemoglobins are changed into the coloured protein cyanomethemoglobin and quantified using a colorimeter in the research. Inadequate samples, whether remaining to insufficient volume or insufficient anticoagulation, might result in misleading findings. If the amount of anemia must be determined rapidly, the hematocrit is a simpler and more convenient test [19].



Scheme 1: Description of the study.

Statistical Analysis

The study was carried out using version 25.0 of the IBM SPSS Statistic software (IBM Corporation, New York, United States). The data was analyzed using descriptive statistics, with results presented as means ± standard deviation (SD). A student t-test with independent samples was used to compare the means of the two groups (patients and controls). In addition, Pearson's correlation analysis is performed in this study to determine the relationships between all research variables. Statistical tests are deemed significant at $p < 0.05$ with a 95% confidence interval, and highly significant at $p \leq 0.01$ with a 99% confidence interval..

Results

The current study's findings revealed that the mean age of the patients was 45.40 years and 42.55 years for the control group, with a non-significant p-value ($p > 0.01$). As demonstrated in Table 1, these findings provide an excellent opportunity to conduct a case study comparing patients with type II diabetes and controls.

Table 1: Anthropometric measurements for patients with type II diabetes and control groups.

	Group	Mean	Std. Deviation	Std. Error Mean	*P*-value
Age	**Control**	42.55	7.40181	1.6551	0.483 NS
	Patient	45.4	8.12663	1.81717	

NS: Non-significant.

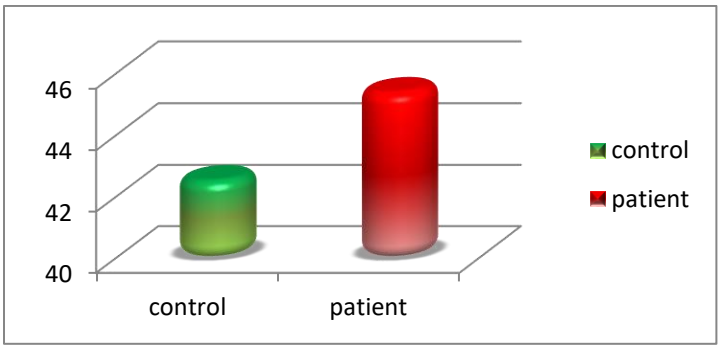


Figure 1: Age values for patient and control groups.

The mean ± SD value of HA1C of the patients was 7.695±1.96, which is significant compared to the values of the control group 4.925±0.61, as shown in Table (2), Figure (2).

Table 2: HbA1C parameters for patients with type II diabetes and control groups.

	Group	Mean	Std. Deviation	Std. Error Mean	*P*-value
HbA1C	**Control**	4.925	0.61974	0.13858	0.001*
	Patient	7.695	1.96615	0.43965	

*** Significant at p <0.01.**

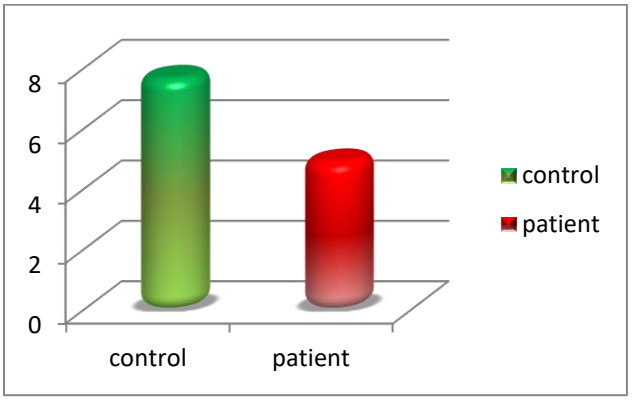


Figure 2: HbA1C values for patient and control groups.

The mean ± SD value of FBS of the patients was 168.4±37.99, which is significant compared to the values of the control group 91±5.43, as shown in Table (3), Figure (3).

Table 3: FBS parameters for patients with type II diabetes and control groups.

	Group	Mean	Std. Deviation	Std. Error Mean	*P*-value
FBS	**Control**	91	5.43865	1.21612	0.001*
	Patient	168.4	37.99363	8.49563	

*** Significant at p <0.01.**

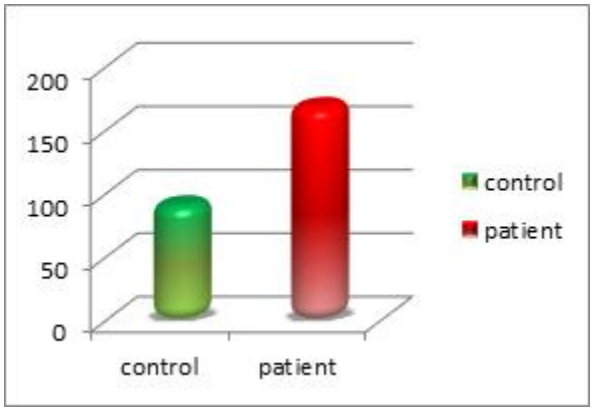


Figure 3: FBS values for patient and control groups.

The mean ± SD value of Hb of the patients was 12±1.91, which is significant compared to the values of the control group 13.5±1.82, as shown in Table (4), Figure (4).

Table 4: Hb parameters for patients with type II diabetes and control groups.

	Group	Mean	Std. Deviation	Std. Error Mean	*P*-value
Hb	**Control**	13.5	1.82093	0.40717	0.645 NS
	Patient	12	1.91943	0.4292	

NS: Non-significant.

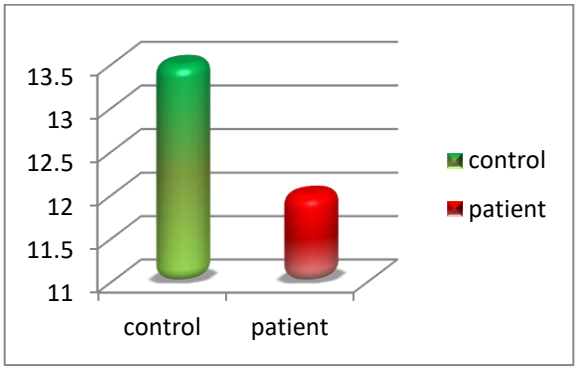


Figure 4: Hb values for patient and control groups.

The Pearson correlation analysis was used to analyse the relationship between HbA1C, CRP, and Hb variables in type II diabetes patients, and the findings are shown in Table 5. The investigation found a favourable association between FBS levels and Hb levels, as shown in Table 5.

Table 5: Correlation coefficients between variables in the patients with type II diabetes group.

	HbA1C	**FBS**	**Hb**
HbA1C	1	-0.103	0.131
FBS	-0.103	1	0.494*
Hb	0.131	0.494*	1

***Correlation is significant at the 0.05 level.**

Discussion

Anemia is a communal comorbidity in individuals with Type II diabetes. The prevalence of anemia is higher in diabetic patients compared to the general population. Anemia in Type II diabetes can result from multiple mechanisms. Chronic inflammation, kidney dysfunction, and poor glycemic control can contribute to the development of anemia [20]. Iron-deficiency anemia can occur in individuals with Type II diabetes due to various factors, including poor dietary habits, gastrointestinal issues, and blood loss [21]. Diabetic nephropathy (kidney disease induced by diabetes) can lead to decreased erythropoietin production, which is a hormone that increases red blood cell synthesis, which can lead to anemia [22].

This study's HbA1C results are consistent with earlier studies' findings, which found greater levels of HbA1C in patients with type II diabetes compared to controls [17], [23]–[26]. In contrast to previous studies, which discovered a low level of HbA1C in type II diabetes individuals [27]–[29]. HbA1c is formed when glucose binds to the N-terminal valine of a Hb molecule's -chain. Because the glycation process is not enzymatic, it is only influenced by time, glucose concentration, and Hb levels. HbA1c is the average glucose concentration to which Hb is exposed over a period of about 106 days. Red blood cells are commonly thought to circulate for around 106 days, with a 20% variation [30]. Some research has found a link between higher HbA1c levels and the incidence of anemia in diabetes individuals. Anemia may be exacerbated by poorly regulated blood sugar levels [31]. HbA1c is a better marker for evaluating glycemic management throughout time than glucose, which only indicates glycemia at one time point. The primary disadvantage of this test is that it may be impacted by the red blood cell life cycle, which varies substantially between individuals [24]. The prevalence of anemia is determined variably based on the population studied and the criteria used. The Third National Health and Nutrition Examination Survey (NHANES), which included a population-based sample of 15,419 persons from the general public in the United States, is one of the larger studies that are most comparable to our study group [32]. The severity of anemia in diabetic patients has been linked to a variety of variables, including glomerular filtration rate, urine albumin

excretion fee, and HbA1C levels[33]. Another notable observation was the relationship between diabetes duration and anemia prevalence. People with diabetes for more than five years are 1.56 times more likely to develop anemia than those with diabetes for less than five years. These findings imply that anemia testing should be preserved within the regular treatment of diabetes patients [23].

Fasting blood sugar (FBS) and anemia are giant fitness concerns, mainly for people with Type II diabetes. Fasting blood sugar (FBS) is a measure of the amount of glucose (sugar) in the bloodstream after an overnight fast [34]. In patients with Type II diabetes, elevated FBS levels are a hallmark of the condition. These individuals have difficulty regulating blood sugar levels, resulting in higher-than-normal glucose levels, especially after periods of fasting [35]. Poorly managed FBS levels in Type II diabetes can lead to a number of problems, including cardiovascular disease, neuropathy, renal disease, and retinopathy [36].

The results of FBS in this study agree with other studies' results that reported higher serum FBS in patients with type II diabetes compared to controls [37]–[40]. HbA1c was shown to be favourably connected with anaemia in diabetic individuals, but FBS was found to be adversely correlated. This implies that the prevalence of anemia is expected to rise in poorly managed diabetes and that lowering blood glucose levels may help minimize the risk of anemia in diabetic populations [37]. Elevated FBS levels can indirectly contribute to anemia in diabetic patients [41]. Uncontrolled diabetes can lead to kidney dysfunction and chronic inflammation, both of which can be factors in the development of anemia [42]. Additionally, high glucose levels can impair the function of red blood cells and reduce their lifespan, potentially worsening anemia [43].

Hemoglobin is a protein present in red blood cells (erythrocytes) that transports oxygen from the lungs to the body's tissues and organs while also returning carbon dioxide to the lungs for expiration [44]. Hemoglobin is essential for maintaining the body's oxygen supply, and its levels can have a significant impact on overall health [45]. The findings of this investigation on HB levels are consistent with recent studies that found no significant difference in HB levels in patients with type II diabetes compared to controls [17], [20], [24]. Anemia is defined as a low Hb level in the blood along with a reduction in the number of functioning red blood cells. Men with Hb concentrations <13.0 g/dL or packed cell volume (PCV) <39% and women with Hb <12.0 g/dL or PCV <36% are classified as anemic by the WHO [46].

Lowering blood glucose levels and aiming for appropriate glycated hemoglobin levels might help lower the risk of anaemia in diabetics. diabetes older adults, who have fewer nutritional options and are more sensitive to iron deficiency anaemia, require immediate diabetes care and control. As a result, doctors should advise them to take iron and vitamin supplements, as well as eat a nutritious iron-rich diet. Iron-rich foods include fish, legumes, whole grains, and nuts. Iron is also added to many processed meals including milk [17].

Conclusions

When compared to the general population, anemia is a prevalent observation among people with type II diabetes. As a result, in diabetic individuals, hemoglobin levels should be checked on a regular basis. Because diabetes mellitus has a high prevalence of anemia, we urge that routine hematological testing, in diabetic outpatient clinics, blood glucose levels must be measured in order to make appropriate treatment decisions for the management of anemia in type II diabetes mellitus. Furthermore, patients should be urged to take their medications as prescribed, and continuing education should be provided to improve physical activity and eating regimen adherence. Correction of anemia may play a significant role in avoiding additional diabetic complications.

References

1. M. Abusaib *et al.*, ‘Iraqi Experts Consensus on the Management of Type 2 Diabetes/Prediabetes in Adults’, *Clin. Med. Insights Endocrinol. Diabetes*, vol. 13, 2020, doi: 10.1177/1179551420942232.

2. C. Ke, K. M. V. Narayan, J. C. N. Chan, P. Jha, and B. R. Shah, 'Pathophysiology, phenotypes and management of type 2 diabetes mellitus in Indian and Chinese populations', *Nat. Rev. Endocrinol.*, vol. 18, no. 7, pp. 413–432, 2022, doi: 10.1038/s41574-022-00669-4.
3. O. Hamdy *et al.*, 'The Transcultural Diabetes Nutrition Algorithm: A Middle Eastern Version', *Front. Nutr.*, vol. 9, 2022, doi: 10.3389/fnut.2022.899393.
4. T. Tuomi, 'Type 1 and Type 2 Diabetes', *Diabetes*, vol. 54, no. suppl_2, pp. S40–S45, 2023, doi: 10.2337/diabetes.54.suppl_2.s40.
5. M. D. E Ahmad, S Lim, R Lamptey, DR Webb, 'Type 2 diabetes', *Pharmaceut. Med.*, vol. 3, no. 4, pp. 389–394, 2023.
6. B. Kumar, N. Bhardwaj, K. Agrawal, and P. Verma, 'Bioethanol Production: Generation-Based Comparative Status Measurements', *Biofuel Prod. Technol. Crit. Anal. Sustain.*, pp. 155–201, 2020, doi: 10.1007/978-981-13-8637-4_7.
7. U. Galicia-Garcia *et al.*, 'Pathophysiology of type 2 diabetes mellitus', *Int. J. Mol. Sci.*, vol. 21, no. 17, pp. 1–34, 2020, doi: 10.3390/ijms21176275.
8. A. Angelousi and E. Larger, 'Anaemia, a common but often unrecognized risk in diabetic patients: A review', *Diabetes Metab.*, vol. 41, no. 1, pp. 18–27, 2015, doi: 10.1016/j.diabet.2014.06.001.
9. B. V. Stefánsson *et al.*, 'Correction of anemia by dapagliflozin in patients with type 2 diabetes', *J. Diabetes Complications*, vol. 34, no. 12, 2020, doi: 10.1016/j.jdiacomp.2020.107729.
10. K. J. Craig *et al.*, 'Anemia and diabetes in the absence of nephropathy', *Diabetes Care*, vol. 28, no. 5, pp. 1118–1123, 2005, doi: 10.2337/diacare.28.5.1118.
11. R. Raichoudhury and B. S. Spinowitz, 'Treatment of anemia in difficult-to-manage patients with chronic kidney disease', *Kidney Int. Suppl.*, vol. 11, no. 1, pp. 26–34, 2021, doi: 10.1016/j.kisu.2020.12.006.
12. J. A. Wright, M. J. Oddy, and T. Richards, 'Presence and Characterisation of Anaemia in Diabetic Foot Ulceration', *Anemia*, vol. 2014, 2015, doi: 10.1155/2014/104214.
13. D. R. Bosman, A. S. Winkler, J. T. Marsden, I. C. Macdougall, and P. J. Watkins, 'Anemia with erythropoietin deficiency occurs early in diabetic nephropathy', *Diabetes Care*, vol. 24, no. 3, pp. 495–499, 2001, doi: 10.2337/diacare.24.3.495.
14. K. W.F. and L. P.A., 'Recent advances in management of type 2 diabetes and nephropathy: Lessons from the RENAAL study', *Am. J. Kidney Dis.*, vol. 41, no. 3 SUPPL. 1, pp. S22–S25, 2003, [Online]. Available: http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L36278339.
15. A. Abate, W. Birhan, and A. Alemu, 'Association of anemia and renal function test among diabetes mellitus patients attending Fenote Selam Hospital, West Gojam, Northwest Ethiopia: A cross sectional study', *BMC Hematol.*, vol. 13, no. 1, 2013, doi: 10.1186/2052-1839-13-6.
16. S. Bolen *et al.*, 'Comparative Effectiveness and Safety of Oral Diabetes Medications for Adults With Type 2 Diabetes.', *Comp. Eff. Rev. No. 8.*, p. 233, 2007, [Online]. Available: http://www.effectivehealthcare.ahrq.gov/repFiles/OralFullReport.pdf.
17. S. M. AlDallal and N. Jena, 'Prevalence of Anemia in Type 2 Diabetic Patients', *J. Hematol.*, vol. 7, no. 2, pp. 57–61, 2018, doi: 10.14740/jh411w.
18. B. A., R. K.T., E. G., and G. B., 'Anemia and associated factors among type-2 diabetes mellitus patients attending public hospitals in Harari Region, Eastern Ethiopia', *PLoS One*, vol. 14, no. 12, p. e0225725,

2019, [Online]. Available: https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0225725&type=printable.

19. F. C. Adamson JW, 'Hemoglobin function, oxygen affinity and erythropoietin', *Annu Rev Physiol.*, vol. 37, p. 351, 1975.
20. M. M. Taderegew, T. Gebremariam, A. A. Tareke, G. Garedew, and Woldeamanuel, 'Anemia and its associated factors among type 2 diabetes mellitus patients attending debre berhan referral hospital, north-east Ethiopia: A cross-sectional study', *J. Blood Med.*, vol. 11, pp. 47–58, 2020, doi: 10.2147/JBM.S243234.
21. I. J. Malesza *et al.*, 'The Dark Side of Iron: The Relationship between Iron, Inflammation and Gut Microbiota in Selected Diseases Associated with Iron Deficiency Anaemia—A Narrative Review', *Nutrients*, vol. 14, no. 17, 2022, doi: 10.3390/nu14173478.
22. X. Yi *et al.*, 'Erythropoietin Mitigates Diabetic Nephropathy by Restoring PINK1/Parkin-Mediated Mitophagy', *Front. Pharmacol.*, vol. 13, 2022, doi: 10.3389/fphar.2022.883057.
23. G. B. Rathod, P. Parmar, S. Rathod, and A. Parikh, 'Prevalence of anemia in patients with Type 2 Diabetes Mellitus at Gandhinagar, Gujarat, India', *Int. Arch. Integr. Med.*, vol. 3, no. 33, pp. 12–16, 2016.
24. M. Suo, D. Wen, W. Wang, and T. Zhang, 'Comparative study on hemoglobin A1c, glycated albumin and glycosylated serum protein in aplastic anemia patients with Type 2 diabetes mellitus', *Biosci. Rep.*, vol. 40, no. 5, 2020, doi: 10.1042/BSR20192300.
25. A. Panda and R. Ambade, 'Prevalence of anemia and its correlation with HBA1c of patients in Type-II diabetes mellitus: A pilot study', *Natl. J. Physiol. Pharm. Pharmacol.*, vol. 8, no. 9, p. 1409, 2018, doi: 10.5455/njppp.2018.8.0621511072018.
26. Y. Umayahara *et al.*, 'Association of glycated albumin to HbA1c ratio with diabetic retinopathy but not diabetic nephropathy in patients with type 2 diabetes', *Clin. Biochem.*, vol. 50, no. 6, pp. 270–273, 2017, doi: 10.1016/j.clinbiochem.2016.11.032.
27. M. Koga *et al.*, 'Usefulness of glycated albumin as an indicator of glycemic control status in patients with hemolytic anemia', *Clin. Chim. Acta*, vol. 412, no. 3–4, pp. 253–257, 2011, doi: 10.1016/j.cca.2010.10.014.
28. D. Kutter and J. Thoma, 'Hereditary spherocytosis and other hemolytic anomalies distort diabetic control by glycated hemoglobin', *Clin. Lab.*, vol. 52, no. 9–10, pp. 477–481, 2006.
29. D. Aslan and T. Gursel, 'The usefulness of glycosylated hemoglobin (HbA1C) in discriminating between iron deficiency and thalassemia', *Pediatr. Hematol. Oncol.*, vol. 23, no. 4, pp. 307–315, 2006, doi: 10.1080/08880010600629528.
30. P. K. Khera *et al.*, 'Use of an oral stable isotope label to confirm variation in red blood cell mean age that influences HbA1c interpretation', *Am. J. Hematol.*, vol. 90, no. 1, pp. 50–55, 2015, doi: 10.1002/ajh.23866.
31. M. I. P. Lubis, 'ASSOCIATION OF GLYCOSYLLATED HEMOGLOBIN (HbA1C) LEVELS TO THE SEVERITY OF DIABETIC FOOT ULCER IN TYPE 2 DIABETES MELLITUS PATIENTS IN RSUP. H. ADAM MALIK MEDAN', *Sumatera Med. J.*, vol. 5, no. 1, 2022, doi: 10.32734/sumej.v5i1.9060.
32. B. C. Astor, P. Muntner, A. Levin, J. A. Eustace, and J. Coresh, 'Association of kidney function with anemia: The Third National Health and Nutrition Examination Survey (1988-1994)', *Arch. Intern. Med.*,

vol. 162, no. 12, pp. 1401–1408, 2002, doi: 10.1001/archinte.162.12.1401.

33. M. C. Thomas, R. J. MacIsaac, C. Tsalamandris, D. Power, and G. Jerums, 'Unrecognized anemia in patients with diabetes: A cross-sectional survey', *Diabetes Care*, vol. 26, no. 4, pp. 1164–1169, 2003, doi: 10.2337/diacare.26.4.1164.
34. A. Ekong, E. Udo, O. Ekong, and S. Inyang, 'Machine Learning based Model for the Prediction of Fasting Blood Sugar Level towards Cardiovascular Disease Control for the Enhancement of Public Health', *Int. J. Comput. Appl.*, vol. 184, no. 52, pp. 5–12, 2023, doi: 10.5120/ijca2023922622.
35. I. Rahman, M. T. Athar, and M. Islam, 'Type 2 Diabetes, Obesity, and Cancer Share Some Common and Critical Pathways', *Front. Oncol.*, vol. 10, 2021, doi: 10.3389/fonc.2020.600824.
36. L. Sacchetta *et al.*, 'Synergistic effect of chronic kidney disease, neuropathy, and retinopathy on all-cause mortality in type 1 and type 2 diabetes: a 21-year longitudinal study', *Cardiovasc. Diabetol.*, vol. 21, no. 1, 2022, doi: 10.1186/s12933-022-01675-6.
37. S. Antwi-Bafour, S. Hammond, J. K. Adjei, R. Kyeremeh, A. Martin-Odoom, and I. Ekem, 'A case-control study of prevalence of anemia among patients with type 2 diabetes', *J. Med. Case Rep.*, vol. 10, no. 1, 2016, doi: 10.1186/s13256-016-0889-4.
38. H. H., A. M., N. O., H. M., and S. G., 'The effect of curcumin supplementation on anthropometric indices, insulin resistance and oxidative stress in patients with type 2 diabetes: A randomized, double-blind clinical trial', *Diabetol. Metab. Syndr.*, 2019.
39. Z. Adab *et al.*, 'Effect of turmeric on body measurement indices, glycemic condition, and lipid profile in hyperlipidemic patients with type 2 diabetes', *Iran. J. Nutr. Sci. Food Technol.*, vol. 8, no. 3, pp. 217–227, 2013, [Online]. Available: https://nsft.sbmu.ac.ir/article-1-1440-en.html.
40. N. Maithilikarpagaselvi, M. G. Sridhar, R. P. Swaminathan, and B. Zachariah, 'Curcumin prevents inflammatory response, oxidative stress and insulin resistance in high fructose fed male Wistar rats: Potential role of serine kinases', *Chem. Biol. Interact.*, vol. 244, pp. 187–194, 2016, doi: 10.1016/j.cbi.2015.12.012.
41. J. Wang *et al.*, 'Anemia and diabetic kidney disease had joint effect on diabetic retinopathy among patients with type 2 diabetes', *Investig. Ophthalmol. Vis. Sci.*, vol. 61, no. 14, 2020, doi: 10.1167/IOVS.61.14.25.
42. J. He, Z. Jia, A. Zhang, and M. Bai, 'Long-term treatment of chronic kidney disease patients with anemia using hypoxia-inducible factor prolyl hydroxylase inhibitors: potential concerns', *Pediatr. Nephrol.*, 2023, doi: 10.1007/s00467-023-06031-8.
43. D. Li *et al.*, 'What Should Be Responsible for Eryptosis in Chronic Kidney Disease?', *Kidney Blood Press. Res.*, vol. 47, no. 6, pp. 375–390, 2022, doi: 10.1159/000522133.
44. S. S. Domínguez, A. F. García, and A. I. Ruiz Chaveco, '[PDF] MATHEMATICAL MODELING OF THE RESPIRATORY PROCESS AND TRANSPORT OF OXYGENATED BLOOD TO THE CELLS OF THE HUMAN ORGANISM', *Int. J. Appl. Sci. Eng. Rev.*, vol. 03, no. 06, pp. 32–42, 2022, doi: 10.52267/ijaser.2022.3603.
45. P. Bhadra and A. Deb, 'A review on nutritional anemia', *Indian J. Nat. Sci.*, vol. 10, no. 59, pp. 18466–18474, 2020.
46. U. Hahn, 'Classification of anaemia', *IMVS Newsl.*, vol. 65, pp. 8–10, 2007.