

Evaluation of Serum Ferritin in Type 2 Diabetes Mellitus: An Observational Study from North Sulawesi, Indonesia

Diana Shintawati Purwanto^{1,2,*}, Yanti Meilen Mewo¹, Stefana Helena Margaretha Kaligis¹, Edmond Leonard Jim³

¹Department of Biochemistry, Faculty of Medicine, Sam Ratulangi University, Manado, Indonesia

²Department of Clinical Laboratory, Prof. Dr. R. D. Kandou Central General Hospital, Manado, Indonesia

³Department of Cardiovascular Medicine, Faculty of Medicine, Sam Ratulangi University, Manado, Indonesia

Email address:

dianashintapurwanto@unsrat.ac.id (Diana Shintawati Purwanto)

*Corresponding author

To cite this article:

Diana Shintawati Purwanto, Yanti Meilen Mewo, Stefana Helena Margaretha Kaligis, Edmond Leonard Jim. Evaluation of Serum Ferritin in Type 2 Diabetes Mellitus: An Observational Study from North Sulawesi, Indonesia. *International Journal of Diabetes and Endocrinology*. Vol. 7, No. 4, 2022, pp. 103-108. doi: 10.11648/j.ijde.20220704.11

Received: September 22, 2022; Accepted: October 10, 2022; Published: October 18, 2022

Abstract: Diabetes mellitus is still an important health problem in Indonesia because the incidence is increasing every year and most patients do not achieve good and proper glycemic control. Analysis of blood ferritin levels in type 2 diabetes mellitus patients is considered limited in many areas. As a marker of iron stores in the body, elevated serum ferritin has been associated with microvascular and macrovascular complications of diabetes mellitus. This study aimed to determine the correlation between serum ferritin levels and fasting blood glucose, glycated hemoglobin (HbA1c), and other biochemical parameters in type 2 diabetes mellitus patients in North Sulawesi, Indonesia. A total of 108 diabetes mellitus patients were included in this cross-sectional study. Subjects were tested for blood pressure, body mass index, fasting blood glucose, hemoglobin, glycated hemoglobin (HbA1c), ferritin, urea, creatinine, uric acid, alanine aminotransferase, aspartate aminotransferase, cholesterol, and triglyceride. The averages of HbA1c% in the good, moderate, and poor groups were $5.70 \pm 0.5\%$, 7.2 ± 0.6 , and 10.1 ± 1.6 , respectively. Increased fasting blood glucose, ferritin, urea, creatinine, and uric acid levels were observed along with worsening glycemic status. There were significant correlations between serum ferritin and fasting blood glucose, glycated hemoglobin, and alanine aminotransferase ($p < 0.05$). There were significantly different mean ferritin values in the three groups of glycated hemoglobin, suggesting ferritin can be used as an indicator of control of glycemia and diabetic complications.

Keywords: Diabetes Mellitus, Ferritin, Glycated Hemoglobin, HbA1c, Blood Glucose

1. Introduction

Diabetes mellitus, a metabolic disorder characterized by hyperglycemia, is still an important global health problem, because it can cause high morbidity and mortality rates. More than 50% of diabetic patients have comorbidities, so the prevalence of diabetic vascular complications such as retinopathy, nephropathy, and other vascular dysfunctions is also increasing [1]. Indonesia ranks seventh out of ten countries with the highest number of people with diabetes (10.7 million) [2]. The incidence of type 2 diabetes mellitus in Indonesia is increasing every year and about 87.5% of patients do not achieve good and appropriate glycemic control [3]. The

financial burden of family and community health is significantly increased by diabetes mellitus and its complications, which in turn contributes significantly to the national burden of healthcare costs [4]. North Sulawesi ranks among the top five of 34 Indonesian provinces with the highest prevalence of diabetes mellitus, according to data from the Indonesian Basic Health Research conducted in 2018 [5]. Analysis of fasting blood glucose (FBG) and glycated hemoglobin related to blood ferritin levels in diabetes mellitus patients is considered limited in this area.

Serum ferritin, an acute phase reactant, is a marker of the body's iron stores. Ferritin testing is generally used to assess iron status in healthy individuals and anemia patients.

There are several ways that increased iron stores can cause diabetes mellitus [6]. Elevated serum ferritin has been linked to long-term microvascular and macrovascular complications of diabetes mellitus in a number of studies [7–9].

The aims of this study were to determine the relationship between serum ferritin levels and fasting blood glucose and glycated hemoglobin (HbA1c), and also to assess whether there was any association of clinical and other biochemical parameters with change in HbA1c and ferritin levels in type 2 diabetes mellitus patients.

2. Material and Methods

2.1. Study Design and Patients

A cross-sectional study was conducted at Noongan Regional General Hospital, Minahasa Regency, North Sulawesi, Indonesia. The timeline of sample collection was May–August 2021. This study was approved by the Medical Research Ethics Committee of R. D. Kandou General Hospital (No. 074/EC/KEPK-KANDOU/V/2021). Written informed consent was taken from all subjects. Populations were all inpatients and outpatients with diabetes mellitus (fasting blood glucose ≥ 126 mg/dL or previous history of diabetes mellitus).

Sample collection used total sampling method, which included all subjects who were examined during the study period and met the inclusion and exclusion criteria, and were willing to participate in this study. Exclusion criteria included the following: a. patients with hemoglobin levels < 10 mg/dL, b. anemia therapy in the last 2 months, c. pregnant patient, d. patients with heart failure, liver disease, hematological disorders, and infection, and e. chronic alcoholics.

2.2. Clinical and Laboratory Data Collection

Systolic and diastolic blood pressure of the participants was measured with an automatic digital aneroid sphygmomanometer. The height was measured with a stadiometer (cm) and weight was measured with a weighing scale (kg). The patients' body mass index (BMI) values were calculated using the formula of weight (kg)/height (m^2). Venous blood was taken from all subjects after overnight fasting.

Serum samples were used for chemical parameters estimation and ethylenediaminetetraacetic acid (EDTA) samples for hemoglobin (Hb) and glycated hemoglobin (HbA1c). Blood glucose, urea, creatinine, uric acid, alanine aminotransferase (ALT), aspartate aminotransferase (AST), total cholesterol, and triglyceride (TG) were assayed using Sysmex BX-3010 chemistry analyzer. Hemoglobin analysis was conducted using Sysmex XN-1000TM hematology analyzer. HbA1c was tested using Epithod[®] 616 analyzer. Serum ferritin was estimated using Roche COBAS e-411. All analysis were performed according to the manufacturer's protocol.

2.3. Statistical Data Analysis

Statistical analysis was performed using the SPSS version 26 software. Diabetic patients were divided into three groups based on HbA1c as follows: good control HbA1c $< 6.5\%$, moderate control $6.5\text{--}8\%$, and poor control $> 8\%$ [7]. The data was represented by number, percentage, and mean and standard deviation (SD). Continuous variables of independent measurements showing normal distribution were analyzed using an independent samples t-test and one-way analysis of variance, while data with abnormal distribution were analyzed using the Mann-Whitney rank sum test and Kruskal-Wallis on the rank test. Variables with abnormal distribution were analyzed using the Spearman's correlation coefficient to identify the relationship between the variables and the direction. A p -value of < 0.05 was considered significant.

3. Results

One hundred and eight blood specimens were collected from diabetes mellitus patients. The patients ranged in from 33 to 80, with an average of 57.2 ± 9.4 years. The majority of subjects were in the age group of 45–54 and 55–64 years, each 36 patients (33.3%), followed by the age group ≥ 65 years (25%). Sixty of 108 patients were females (55.6%), 8.3% of patients were receiving insulin, 2.8% were receiving insulin in combination with an oral antidiabetic, and 88.9% of patients were taking oral antidiabetics. We observed that majority of subjects had overweight BMI (51%).

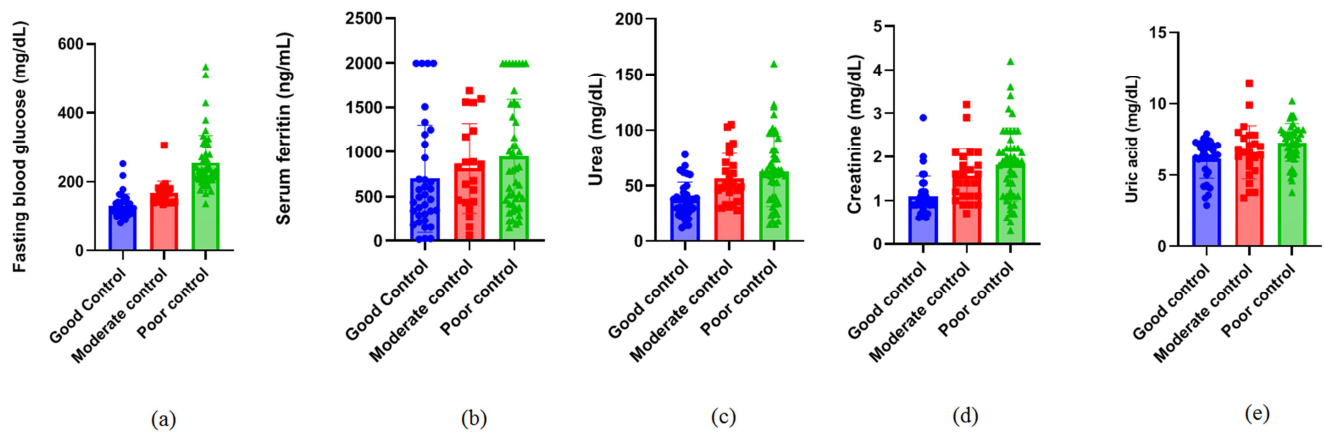
Diabetic patients were divided into three groups based on their HbA1c: good control 35 cases (32.4%), moderate control 24 cases (22.2%), and poor control 49 cases (45.4%). Baseline characteristics of the groups are shown in Table 1.

Fasting blood glucose, ferritin, urea, creatinine, and uric acid levels were observed to rise as the glycemic status deteriorated (Figure 1). With a correlation coefficient (r) of 0.844, which indicates a very strong and positive correlation (directly proportional), there was a correlation between HbA1c levels and FBG, as shown in Figure 2a. The null hypothesis was rejected on the basis of the significance test, which indicated that there was a significant relationship between HbA1c levels and FBG levels. The correlation coefficient (r) between ferritin levels and FBG was 0.206, indicating a weak and directly proportional relationship. The fact that the p -value was 0.040 (< 0.05) indicated that there was a significant correlation between the levels of FBG and serum ferritin (Figure 2b). The correlation coefficient (r) between ferritin levels and HbA1c was 0.199, indicating that there was a very weak and positive correlation. Figure 2c shows that there was a significant relationship between ferritin concentrations and HbA1c, with a p -value of 0.048 ($p < 0.05$).

Another biochemical parameter, alanine aminotransferase, had a significant correlation with ferritin (r 0.429 and p -value 0.023). The others parameters in the Spearman's correlation analysis did not show significant correlations with ferritin.

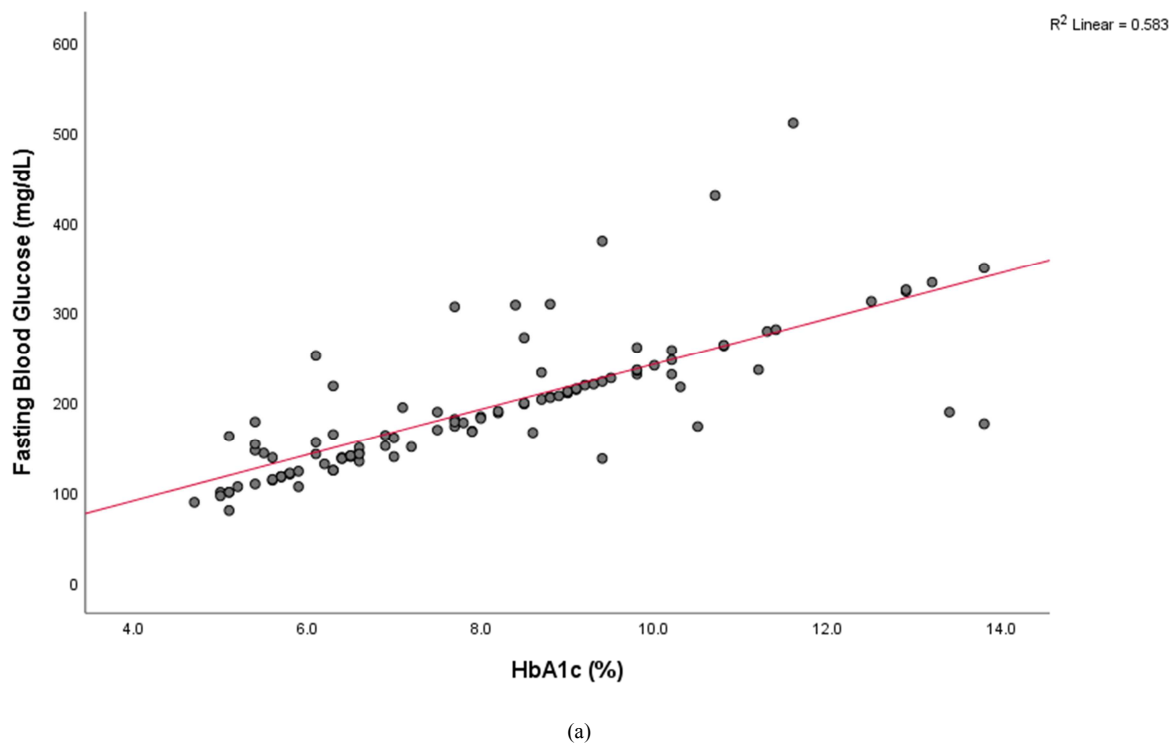
Table 1. Baseline characteristics of diabetic patients.

Characteristic	Good control		Moderate control		Poor control		p-value
	mean \pm Standard Deviasi	median (min-max)	mean \pm Standard Deviasi	median (min-max)	mean \pm Standard Deviasi	Median (min-max)	
BMI (kg/m ²)	24.5 \pm 3.0	25.3 (14.9-29.4)	25.5 \pm 3.0	25.6 (20.3-33.9)	25.0 \pm 3.5	25.2 (18.4-33.9)	0.735
SBP (mmHg)	138.0 \pm 24.4	140 (90-190)	129.8 \pm 21.2	130 (100-200)	132.0 \pm 22.5	130 (100-180)	0.198
DBP (mmHg)	83.4 \pm 17.1	90.0 (60.0-151)	81.5 \pm 12.5	80.0 (60.0-110)	81.7 \pm 22.5	80.0 (50.0-110)	0.357
Hemoglobin (g/dL)	12.7 \pm 1.9	13.4 (6.8-15.1)	11.9 \pm 2.0	11.6 (7.9-15.1)	11.8 \pm 2.0	12.0 (7.0-15.5)	0.086
HbA1c (%)	5.70 \pm 0.5	5.70 (4.70-6.40)	7.2 \pm 0.6	7.15 (6.50-8.00)	10.1 \pm 1.6	9.65 (8.20-13.80)	<0.001*
FBG (mg/dL)	131.1 \pm 34.3	123 (80.0-252)	167.4 \pm 34.7	165 (134-306)	254.8 \pm 79.8	231 (137-534)	<0.001*
Ferritin (ng/mL)	699.1 \pm 603.9	495 (18-2000)	816.9 \pm 503.5	754 (62-1686)	955.9 \pm 634.3	793 (149-2000)	0.125
Urea (mg/dL)	37.2 \pm 16.1	36.0 (12.0-78.0)	56.6 \pm 22.5	50.0 (12.0-78.0)	62.9 \pm 31.4	61.0 (15.0-160.0)	<0.001*
Creatinine (mg/dL)	1.1 \pm 0.5	1.0 (0.6-2.9)	1.6 \pm 0.6	1.5 (0.7-3.2)	1.8 \pm 0.8	1.9 (0.3-4.2)	<0.001*
Uric acid (mg/dL)	6.1 \pm 1.4	6.4 (2.9-7.9)	6.6 \pm 1.9	6.6 (3.4-11.4)	7.3 \pm 1.3	7.6 (3.8-10.2)	0.001*
ALT (U/L)	23.0 \pm 10.4	19.0 (10.0-42.0)	35.5 \pm 18.2	31.0 (16.0-66.0)	32.0 \pm 20.5	27.0 (10.0-69.0)	0.306
AST (U/L)	23.6 \pm 8.6	19.0 (14.0-37.0)	34.3 \pm 15.0	33.0 (14.0-60.0)	26.3 \pm 12.8	19.5 (14.0-45.0)	0.341
Cholesterol (mg/dL)	199.9 \pm 27.4	210 (149-228)	163.3 \pm 60.7	159 (76-251)	191.2 \pm 40.3	242 (137-242)	0.368
TG (mg/dL)	163.2 \pm 62.8	143 (87-291)	146.9 \pm 59.9	140 (58-224)	133.2 \pm 36.5	138 (67-180)	0.656



(a) fasting blood glucose, (b) ferritin, (c) urea, (d) creatinine, and (e) uric acid.

Figure 1. Comparison of biochemical parameters levels based on HbA1c groups.



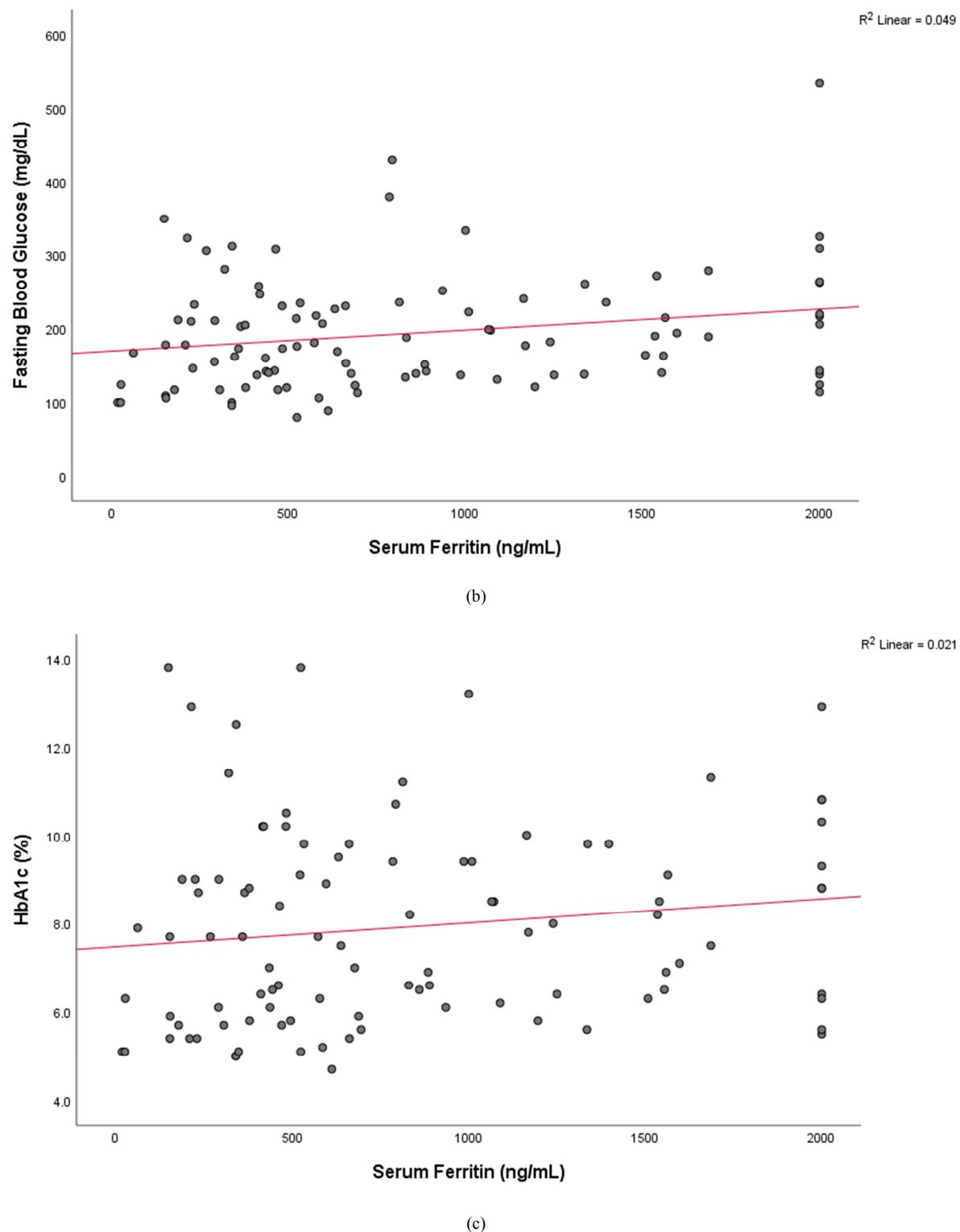


Figure 2. Correlation between (a) HbA1c and fasting blood glucose (b) ferritin and fasting blood glucose, and (c) ferritin and HbA1c.

4. Discussion

The results of this study indicate that diabetes mellitus is mostly suffered by subjects aged 45-54 and 55-64 years old. The average peak age of type 2 DM diagnosis is between 45-60 years [10]. The prevalence of subjects ≥ 65 years (25%)

was similar to those of U.S. adults, which varies from 22 to 33% [11]. Older adults with diabetes are particularly vulnerable to having acute and chronic microvascular and cardiovascular complications from this disease [12]. This study also shows that females are more likely than males to have diabetes mellitus. This finding agrees with prior studies, however contradicts Borah's study [13-15].

This study indicates that the poor control group has the highest fasting blood glucose and serum ferritin. These findings are consistent with those of previous studies [5, 13–17]. Several possible mechanisms have been suggested for the correlation between elevated serum ferritin and the incidence of type 2 diabetes, although the precise mechanism is unknown. Iron deposition in the liver, one of these mechanisms, can increase hepatic glucose production and cause hepatic insulin resistance [8, 18, 19]. Furthermore, elevation of oxidative stress due to increased formation of hydroxyl radicals catalysed by iron, can cause systemic insulin resistance and hyperglycemia [20–22]. Other studies have suggested that iron excess contributes to insulin resistance and subsequently to decreased insulin secretion [23, 24]. Lastly, higher ferritin levels in non-alcoholic fatty liver disease (NAFLD) reflect abnormal iron metabolism or inflammation, and NAFLD is a risk factor for the development of type 2 diabetes [25].

Our study shows a very strong and directly proportional correlation between fasting blood glucose and HbA1c. There are many studies conducted worldwide indicating significant relationship between the two [8]. However, a meta-analysis conducted by Ketema *et al.* [26] reported, although correlation coefficient was 0.61 between FPG and HbA1c values, in the absence of HbA1c, it was discovered that monitoring of postprandial plasma glucose (PPG) was a better parameter for predicting or achieving target HbA1c values than FPG alone.

The averages of HbA1c% in the good, moderate, and poor groups in this study were $5.70 \pm 0.5\%$, 7.2 ± 0.6 , and 10.1 ± 1.6 , respectively. The mean HbA1c% value was significantly highest in the poor group among others, indicating that patients' glycemic control worsened [8]. Poor glycemic control may be caused by inactivity, a poor diet, or a lack of medication compliance for diabetics. This study shows a positive correlation between increased serum ferritin and poor glycemic control, reflected by higher HbA1c%. This finding is supported by various studies [6, 7, 15, 16, 27–29]. Apart from serum ferritin and HbA1c%, the urea, creatinine, and uric acid levels were significantly higher in the poor group than others. This finding is similar to result of Amartei *et al.* [30] that kidney dysfunction is more prevalent in diabetics than in non-diabetics. As a result, in diabetic patients, serum levels of urea and creatinine can be used as useful prognostic markers and predictors of renal failure [31, 32].

In the present study, there is a significant correlation between ferritin and alanine aminotransferase, as one of the hepatic enzymes. Cugy *et al.* [33] in a cohort study reported a significant relationship between ferritin and hepatic enzymes and inflammatory markers (ALT, AST, and gamma glutamyl transferase). In NAFLD, the most common abnormality in the liver is an elevated serum alanine aminotransferase (ALT) level [34].

This study has limitations. First, the small sample size may weaken the statistical power of our results. Second, this was a cross sectional study without longitudinal follow-up, therefore we were unable to determine a causal relationship between serum ferritin and fasting blood glucose, glycated hemoglobin, and

alanine aminotransferase or other variables of diabetes mellitus.

5. Conclusion

This study concluded that there are significant correlations between serum ferritin and fasting blood glucose, glycated hemoglobin, and alanine aminotransferase. Mean ferritin values are significantly different in the three groups of glycated hemoglobin, therefore ferritin can be used as an indicator of control of glycemia and diabetic complications. Further studies on the causal relationship between elevated serum ferritin and laboratory parameters of diabetes mellitus are warranted.

Conflict of Interest Statement

All the authors do not have any possible conflicts of interest.

Acknowledgements

The authors would like to thank the Noongan Regional General Hospital, Biochemistry Department, Faculty of Medicine, and Sam Ratulangi University for all of their assistance, as well as all of the patients who participated in this study. Through the RDUU research scheme for fiscal year 2021, the Directorate of Research and Community Service at Sam Ratulangi University Manado, Indonesia, provided financial support for this study.

References

- [1] Young EE, Okafor CN, Okwara CC. Diabetes mellitus, associated co-morbidities and complications - A review. *Int Res J Med Med Sci* 2016; 07 (03): 47-55.
- [2] World Health Organization. Global report on diabetes. Working Papers 2016; id: 10553, eSocial Sciences.
- [3] Pamungkas RA, Chamroonsawasdi K. Family Functional-based Coaching Program on Healthy Behavior for Glycemic Control among Indonesian Communities: A Quasi-experimental Study. *Oman Med J* 2020; 35 (5): e173–e173.
- [4] Pamungkas RA, Chamroonsawasdi K. Self-management based coaching program to improve diabetes mellitus self-management practice and metabolic markers among uncontrolled type 2 diabetes mellitus in Indonesia: A quasi-experimental study. *Diabetes Metab Syndr Clin Res Rev* 2020; 14 (1): 53–61.
- [5] Badan Penelitian dan Pengembangan Kesehatan. Hasil Utama RISKESDAS 2018. Kementerian Kesehatan RI; 2018.
- [6] Arora P. Correlation between Serum Ferritin and glycated Hb level in patients of type 2 DM. *Int J Cur Res Rev* 2017; 9 (6), 30-3.
- [7] Rawat N, Mathur N, Harikrishnan R, Choudary J, Rawat K, Mathur M. A study of correlation of serum ferritin with glycated hemoglobin in diabetes mellitus type 2 patients: a case control study. *Asian Pac J Health Sci* 2016; 3 (4), 83–8.

- [8] Son NE. Influence of ferritin levels and inflammatory markers on HbA1c in the Type 2 Diabetes mellitus patients. *Pak J Med Sci* 2019; 35 (4): 1030-5.
- [9] Rajpathak S, Ma J, Manson J, Willett WC, Hu FB. Iron Intake and the Risk of Type 2 Diabetes in Women: A prospective cohort study. *Diabetes Care* 2006; 29 (6): 1370-6.
- [10] Kaleru T, Vankeshwaram VK, Maheshwary A, Mohite D, Khan S. Diabetes Mellitus in the Middle-Aged and Elderly Population (>45 Years) and Its Association With Pancreatic Cancer: An Updated Review. *Cureus* 2020; 12 (6): e8884-e8884.
- [11] Kirkman MS, Briscoe VJ, Clark N, Florez H, Haas LB, Halter JB, et al. Diabetes in Older Adults. *Diabetes Care* 2012; 35 (12): 2650-64.
- [12] LeRoith D, Biessels GJ, Braithwaite SS, Casanueva FF, Draznin B, Halter JB, et al. Treatment of Diabetes in Older Adults: An Endocrine Society* Clinical Practice Guideline. *J Clin Endocrinol Metab* 2019; 104 (5): 1520-74.
- [13] Purwanto DS, Laloan RJ, Raranta HPT, Kepel BJ. Electrolyte Levels Analysis on Diabetes Mellitus Patients in Noongan Regional General Hospital, North Sulawesi, Indonesia. *Int J Diabetes Metab* 2020; 5 (4), 54-60.
- [14] Sobers-Grannum N, Murphy MM, Nielsen A, Guell C, Samuels TA, Bishop L, et al. Female Gender Is a Social Determinant of Diabetes in the Caribbean: A Systematic Review and Meta-Analysis. *Wu Q, editor. PLOS ONE* 2015; 10 (5): e0126799.
- [15] Borah M, Goswami R. Evaluation of serum ferritin in in type II diabetes mellitus: a hospital based observational study from Dibrugarh, Assam, India. *Int J Res Med Sci* 2016; 4 (11): 4916-21.
- [16] Sharifi F, Sazandeh S. Serum ferritin in type 2 diabetes mellitus and its relationship with HbA1c. *Acta Med Iran* 2004; 42 (2): 142-5.
- [17] Canturk Z, Çetinarslan B, Tarkun İ, Zafer Canturk N. Serum Ferritin Levels in Poorly- and Well-Controlled Diabetes Mellitus. *Endocr Res* 2003; 29 (3): 299-306.
- [18] Altamura S, Müdder K, Schlotterer A, Fleming T, Heidenreich E, Qiu R, et al. Iron aggravates hepatic insulin resistance in the absence of inflammation in a novel db/db mouse model with iron overload. *Mol Metab* 2021; 51: 101235.
- [19] Thomas MC, MacIsaac RJ, Tsalamandris C, Jerums G. Elevated iron indices in patients with diabetes: Short report. *Diabet Med* 2004; 21 (7): 798-802.
- [20] Tangvarasittichai S. Oxidative stress, insulin resistance, dyslipidemia and type 2 diabetes mellitus. *World J Diabetes* 2015; 6 (3): 456-80.
- [21] Ito F, Sono Y, Ito T. Measurement and Clinical Significance of Lipid Peroxidation as a Biomarker of Oxidative Stress: Oxidative Stress in Diabetes, Atherosclerosis, and Chronic Inflammation. *Antioxidants* 2019; 8 (3): 72.
- [22] Avelar TMT, Storch AS, Castro LA, Azevedo GVMM, Ferraz L, Lopes PF. Oxidative stress in the pathophysiology of metabolic syndrome: which mechanisms are involved? *J Bras Patol E Med Lab* 2015; 51 (4): 231-9.
- [23] Jiang R. Body Iron Stores in Relation to Risk of Type 2 Diabetes in Apparently Healthy Women. *JAMA* 2004; 291 (6): 711.
- [24] Zhao Z, Li S, Liu G, Yan F, Ma X, Huang Z, et al. Body Iron Stores and Heme-Iron Intake in Relation to Risk of Type 2 Diabetes: A Systematic Review and Meta-Analysis. *Ye J, editor. PLoS ONE* 2012; 7 (7): e41641.
- [25] Utzschneider KM, Largajolli A, Bertoldo A, Marcovina S, Nelson JE, Yeh MM, et al. Serum ferritin is associated with non-alcoholic fatty liver disease and decreased B-cell function in non-diabetic men and women. *J Diabetes Complications* 2014; 28 (2): 177-84.
- [26] Ketema EB, Kibret KT. Correlation of fasting and postprandial plasma glucose with HbA1c in assessing glycemic control; systematic review and meta-analysis. *Arch Public Health* 2015; 73 (1): 43.
- [27] Khondker F, Roy MN, Saha PR, Huq R, Ahmed R, Biswas S. Relationship Between Serum Ferritin Level and HbA1c in Bangladeshi Type 2 Diabetic Patients. *Anwer Khan Mod Med Coll J* 2018; 9 (1): 29-33.
- [28] Moirangthem MM, Rajkumari VD. Study of Serum Ferritin and HbA1c Levels in Type 2 Diabetes Mellitus. *J Evid Based Med Healthc* 2020; 7 (27): 1282-5.
- [29] Raj S, Rajan G. Correlation between elevated serum ferritin and HbA1c in type 2 diabetes mellitus. *Int J Res Med Sci* 2013; 1 (1): 12.
- [30] Amartey NAA, Nsiah K, Mensah FO. Plasma Levels of Uric Acid, Urea and Creatinine in Diabetics Who Visit the Clinical Analysis Laboratory (CAn-Lab) at Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. *J Clin Diagn Res.* 2015; 9 (2): BC05-09.
- [31] Adler AI, Stevens RJ, Manley SE, Bilous RW, Cull CA, Holman RR, et al. Development and progression of nephropathy in type 2 diabetes: The United Kingdom Prospective Diabetes Study (UKPDS 64). *Kidney Int* 2003; 63 (1): 225-32.
- [32] Bamanikar S, Bamanikar A, Arora A. Study of Serum urea and Creatinine in Diabetic and non- diabetic patients in a tertiary teaching hospital. *J Med Res* 2016; 2 (1): 12- 5.
- [33] Cugy D. Relationship of morningness-eveningness questionnaire score to ferritin, gamma glutamyl-transpeptidase and alanine amino-transferase concentrations in a large cohort. *Sleep Med Disord Int J* 2018; 2 (3): 60-5.
- [34] Choi KM, Lee KW, Kim HY, Seo JA, Kim SG, Kim NH, et al. Association among serum ferritin, alanine aminotransferase levels, and metabolic syndrome in Korean postmenopausal women. *Metabolism* 2005; 54 (11): 1510-4.