International Journal of Public Health Science (IJPHS)
Vol. 14, No. 2, June 2025, pp. 898~903
ISSN: 2252-8806, DOI: 10.11591/ijphs.v14i2.25569

Relationship between iron deficiency anemia and glycosylated hemoglobin in diabetes patients

Saida Fuad Shnaigat, Baha'a M. Abu Salma
Department of Nutrition and Food Sciences, Faculty of Agriculture, Jerash University, Jerash, Jordan

Article Info

Article history:

Received Jul 21, 2024
Revised Nov 12, 2024
Accepted Jan 9, 2025

Keywords:

Anemia
Diabetes mellitus
Ferritin
HbA1c
Transferrin

ABSTRACT

The study aimed to investigate the relationship between iron metabolism indicators such as ferritin and transferrin levels and glycosylated hemoglobin. Another goal of the current study is to draw the attention of the scientific and medical community to a very important issue regarding diagnostic and follow-up the diabetic patients which is the effect of iron status on HbA1c level. A cross-sectional study was conducted on (n=300) participants. The participant was assigned into three groups: the diabetes group (n=101), the prediabetes group (n=100), and the control group (n=99). A structured questionnaire with sociodemographic data and biochemical tests was applied. The results of the study found that there were significant differences in age among groups (p=0.05), with the diabetic group being younger than other groups. There is a direct positive relationship between HbA1c levels and ferritin (β=2%, p=0.001) and fasting blood sugar (β=1.8%, p=0.001). The findings also show an inverse relationship between glycosylated hemoglobin and transferrin (β=0.1%, p=0.001), as well as mean corpuscular volume (MCV) (β=1.8%, p=0.001). The study finding confirms a positive correlation between HbA1c with ferritin levels and a negative association with transferrin. Iron status in diabetes patients' treatment plans should considered while the interpretation of the HbA1c concentrations. In addition, diabetes patients' treatment plans should take ferritin level adjustment into account.

Corresponding Author:

Baha'a M. Abu Salma
Department of Nutrition and Food Sciences, Faculty of Agriculture, Jerash University
Jerash, Jordan
Email: bahaabusalma@gmail.com or b.abusalma@jpu.edu.jo

1. INTRODUCTION

Diabetes mellitus is a major public health concern all over the world. In 2021, approximately 537 million people have diabetes worldwide, with 90% having type 2 diabetes [1]. Jordan has a diabetes prevalence rate of about 14.8%, placing it tenth in the Arab world for both type 1 and type 2 diabetes [2]. Diabetes is a leading factor in developing micronutrient deficiency, one of the most common micronutrient deficits is iron deficiency anemia (IDA) [3].

The relationship between diabetes and IDA is complicated and still not fully understood. Diabetes causes gastrointestinal bleeding, and reduced iron absorption [4]. However, glycosylated hemoglobin (HbA1c) is an indicator of blood sugar control in the past three months and it is affected by anemia [5]. Chronic IDA, on the other hand, causes prolonged erythrocyte survival, persistent hypoxia, and insufficient hemoglobin (Hb) production, which will affect nonenzymatic glycosylation and the rise of HbA1c [6]. A prospective randomized control study has shown that IDA significantly increases HbA1c concentration and treatment of that IDA with iron will significantly decrease it [7]. Moreover, a study conducted by Altuntaş *et al*. [8] found that IDA was associated with lower HbA1c concentration. A systematic meta-analysis of six studies found that HbA1c did

not accurately reflect the blood sugar control of a diabetic person [9]. In addition, HbA1c concentration was positively significant with Hemoglobin (Hb), ferritin, and red blood cell (RBC) count, and HbA1c concentration was inversely associated with the Hb concentration [10]. On the other hand, the study of Soliman *et al*. [11], showed a positive correlation between HbA1c with HB and ferritin in non-diabetes women.

IDA can impair blood glucose homeostasis, which negatively affects blood glucose control, and predisposes to diabetes complications [6]. There is a relationship between hyperglycemia and proinflammatory cytokine. Proinflammatory cytokine is associated with the development of insulin resistance and diabetes complications such as renal impairment [1], [12]. Proinflammatory markers, especially IL-6, decrease erythropoietin production from renal interstitial cells, which, reduces erythrocyte production causing a reduction in Hb levels [13]. Moreover, inflammatory conditions associated with kidney disease interfere with iron absorption and lead to anemia [14].

The study explores the relationship between IDA and HbA1c levels, highlighting the potential for overestimation or underestimation of glycemic control, leading to misdiagnosis and inappropriate diabetes management. The study highlights the negative impact of IDA on glycemic control, suggesting alternative monitoring strategies like continuous glucose monitoring and optimizing metabolic control through iron repletion. Therefore, the purpose of this study was to investigate the relationship between iron metabolism indicators such as ferritin and transferrin levels and HbA1c concentration among diabetes persons.

2. METHOD

2.1. Study design and sampling

An observational study was conducted in 2018 that included (n=300) participants from multicenter internal medicine outpatient clinics in Ajloun Governorate in northern Jordan. Participants aged 18-70 years were diagnosed with prediabetes or diabetes type I or II, and are willing to participate are included in the study. The participants who had previously been diagnosed with chronic kidney illness, liver disease, hemolytic anemia, heart failure, an active infection, or chronic inflammation, individuals below 18 years old, and pregnant or lactating women were excluded from the study. This study was conducted according to the guidelines laid down in the Declaration of Helsinki. The consent form was filled out by the participants before their enrollment in the study. Ethical approval was not obtained because participation in the study was entirely voluntary, participants' anonymity was ensured, and the data collected were non-sensitive in nature. Three groups of participants were formed: the diabetes group (n=101), the prediabetes group (n=100), and the control group (n=99). Participants were interviewed by a trained nurse to collect sociodemographic data such as age, gender, smoking status, and prior and current health issues.

2.2. Sample size

The sample size for the study was determined using the Raosoft online sample size calculator. The calculation was based on a margin of error set at 5%, a confidence level of 95%, and an assumed response distribution of 50%. An additional 10% was added to the calculated value to account for potential non-responses or incomplete data, resulting in a final required sample size of 300 participants.

2.3. Anthropometrics measurement

2.3.1. Weight, height, and BMI

All participants underwent physical examinations to determine their height (m), and weight kilogram (kg) by calibrated digital scale (Tcs-200lp). The participant's weight was measured with light clothes and bare feet by using a portable digital floor scale (300 kg digital floor bench scale electronic platform postal shipping). The mean of three measurements was taken to the nearest 0.1 kg.

The participant’s height was measured by standing up barefoot and looking straight ahead while measuring the height. The mean of three measurements was taken in centimeters (cm) to the nearest 0.1 cm. Body mass index (BMI) was calculated by dividing weight in kg, by height square in meters (kg/m^2). The BMI was calculated according to World Health Organization (WHO) criteria [15], normal weight (18.5-25.9), overweight (25-29.9), obese class I (30-34.9), obsess class II (35-39.9), and morbid obesity (>40).

2.3.2. Waist hip ratio

Waist circumference (WC), and hip circumference (HC) were measured by a flexible ruler sewing non-elastic tape to the nearest 0.1 cm. The hip was measured over light clothes with the arm relaxed and at the maximum circumference over the buttocks. The waist circumference was measured at the midpoint of the last palpable rib and the top of the hip bone. The mean of three measurements was taken to the nearest 0.1 cm.

2.4. Biochemical analysis

After overnight fasting, a qualified laboratory technician at outpatient clinics in Ajlun took a blood sample from the participants. A commercial enzymatic biochemical test was used to measure the biochemical tests. The following are some of the instruments and devices used in conducting the laboratory testing CBC autoanalyzer Mandary BC-2800, Sysmex XS 1000i CBC autoanalyzer, URIT 3300CBC Autoanalyzer, and Ves-Matic Automated ESR Analyzer. The laboratory tests include Hb, mean corpuscular volume (MCV), serum ferritin, fasting blood glucose (FBS), hemoglobin A1c (HbA1c), Triglyceride (TG); high-density lipoprotein (HDL); low-density lipoprotein (LDL); glomerular filtration rate (GFR); Alanine aminotransferase (ALT); aspartate aminotransferase (AST) and c-reactive protein (C-RP) were measured for all participants**.**

2.5. Statistical analysis

The statistical analysis was carried out using the Statistical Package for Social Science (SPSS) program version 22.0 (SPSS Inc., Chicago, Illinois, USA). Data for continuous variables is displayed as a percentage and mean. The paired sample t-test was used to compare the treatment groups. A one-way ANOVA was used to compare the level of significance between treatment groups. The Pearson correlation coefficient method was used to determine the magnitude and direction of the relationship between dependent and independent variables. The multiple linear regression model was used to determine the relationship between variables. In all analyses, a $p<0.05$ was considered statistically significant.

3. RESULTS AND DISCUSSION

Table 1 displays the baseline characteristics of the study participants. Data analysis was conducted with 300 participants who met the inclusion criteria. There was no significant difference ($p>0.05$) between groups for sex, smoking, BMI, and WHR. Furthermore, there was a significant age difference between groups ($p=0.05$); the diabetic group appears to be younger than the other groups. There were significant differences in hip and waist circumference means between groups. Table 2 displays the biochemical markers of study participants. The results show that the control group had a higher mean value of MCV, and a lower level of TG, HDL, and C-RP ($p=0.05$). Those with diabetes, on the other hand, had significantly ($p\leq0.05$) higher plasma levels of ferritin, HbA1c, and FBS.

Table 1. Baseline characteristics of the participants

Parameter	Diabetes group (n=101)	Pre-diabetes group (n=100)	Control group (n=99)	p	Parameter	Diabetes group (n=101)	Pre-diabetes group (n=100)	Control group (n=99)	p
Women, n (%)	54 (36.2%)	55 (36.9%)	40 (26.8%)	0.07	Height (m)	167±9	168±9	170±10	0.20
Men, n (%)	47 (31.1%)	45 (29.8%)	59 (39.1%)		Weight (kg)	83±13	78±13	79±16	0.06
Age (mean±SD)	58±16	54±16.2	52±14.8	0.02*	BMI (kg/m^2)	29.57±6	28.01±5.6	27.8±7.2	0.09
Smoking				0.70	WC (cm)	66.1±7.4	64.5±7.2	70.6±11	0.001
Yes	25 (29.45)	31(36.5%)	29 (34.1%)	0.20	HC (cm)	69.9±11	65.4±13	69.9±11	0.04
No	73 (34.1%)	69 (32.2%)	72 (33.6%)	0.06	WHR	1.01±1.4	1.01±0.13	1.03±0.17	0.4

Note: Data are expressed as mean ± SD, p-value <0.05 represents the difference between the three groups

Table 2. Biochemical markers of the study population

Biomarker	Diabetes group (n=101)	Pre-diabetes group (n=100)	Control group (n=99)	p-value
Hemoglobin mmol/L	8.3±1.2	8.2±1.2	8.1±1.3	0.500
MCV	80.3±13	80.7±8	84.1±6.7	0.010
FBS mmol/L	16.4±122	8.0±51.2	5.4±20.5	0.001
HbA1c	10.1 ±1.8	6.6±0.8	5.04 ±0.5	0.001
TG mmol/L	6.5±3.4	6.6±3.4	5.1±2.7	0.001
HDL mmol/L	3.0±0.5	2.8±0.4	2.8±0.4	0.010
Cholesterol mmol/L	8±6	8±2.6	7.5±1.7	0.600
LDL mmol/L	5.9±1.1	6.1±1.0	5.9±1.0	0.300
Ferritin mmol/L	10.4±5.4	7.7±3.7	8.7±3.6	0.001
Transferrin mmol/L	12.9±3.8	13.9±4.0	11.4±2.4	0.002
GFR ml/min/1.73m^2	107.9±47.3	119.9±55.2	99.1±24.7	0.005
Creatinine mmol/L	0.1±0.1	0.04±0.04	0.06±0.03	0.004
ALT U/L	32±20.7	29.5±17.7	30.5±18.5	0.600
AST U/L	25.5±11	24.8±11.2	26.1±11.4	0.700
CRP mg/l	7.3±1.8	7.8±1.8	6±2.2	0.001

Note: Data are expressed as mean ± SD, p-value <0.05 represents the difference between the three groups

The most common type of anemia in the world is caused by an iron deficiency. HbA1c can be used to assess a person's glycemic status for a long period. It is frequently used for diabetic patients and those with impaired glucose tolerance. The correlation between HbA1c and (ferritin, MCV, transferrin, and FBS) is presented in Table 3. Pearson correlation coefficient measures the strength and direction of the linear relationship between HbA1c and each independent variable (ferritin, MCV, transferrin, and FBS). The results revealed a significant (p-value<0.05) positive correlation between HbA1c and (ferritin, MCV, and transferrin) levels. The Pearson correlation coefficient between HbA1c and ferritin is (0.33, P=0.001), MCV is (0.37, p=0.001), transferrin is (0.33, p=0.001), and FBS is 0.40 (p=0.001). The model was tested for normality using the Shapiro-Wilk Test. However, a multiple linear regression model was used to understand the effect of each independent variable on HbA1c concentration. The value of the (F) test was (73) and the R^2 value was 76%, which means that approximately 76% of the change in HbA1c can be attributed to the independent variables being studied (ferritin, MCV, transferrin, and FBS). Furthermore, there is a direct positive relationship between HbA1c levels and ferritin (β=2%, p=0.001) and FBS (β=1.8%, p=0.001). The findings also show an inverse relationship between HbA1c and transferrin (β=0.1%, p=0.001), as well as MCV (β=1.8%, p=0.001). The linear form of the regression model was adopted, which is in the following standard form:

$$Y_i = 6.1 + 2\ X_1 + -1.8\ X_2 + 0.1\ X_3 + 1.8\ X_{4+}\ e_i$$

Where Y_i = HbA1c level, X_1= ferritin, X_2= MCV, X_3= transferrin, X_4 = FBS.

Table 3. Correlation between ferritin, MCV, transferrin, FBS, and HbA1c concentration

Parameter	HbA1c concentration				
	B	Pearson correlation	R square	F	p-value
Constant	6.1		0.76	73	0.00
Ferritin	2	0.33			0.03
MCV	-1.8	0.37			0.001
Transferrin	-0.1	0.33			0.01
FBS	1.8	0.40			0.001

Note: Mean corpuscular volume (MCV); Haemoglobin A1c (HbA1c); Fasting blood sugar (FBS). p-value<0.01 was considered statistically significant

Numerous studies have been conducted to examine the relationships between serum ferritin levels and HbA1c levels [16]. Moreover, the results of our study concluded that participants with higher FBS, and ferritin are associated with higher HbA1c concentrations. The result confirms that abnormal iron metabolism plays a role in the pathogenesis of insulin resistance and the development of diabetes type II [17], [18]. Investigated the impact of IDA on HbA1c levels among controlled diabetics during the last three months. The results showed that the mean HbA1c was significantly higher among controlled diabetics with IDA than those without IDA. Moreover, HbA1c does not reflect blood glucose control over the past three months in diabetic persons [19]. A recent study was conducted on diabetes women with IDA and they found that the absolute HbA1c level was significantly lower in the mild and moderate-severe anemia groups than the non-anemic group, and was positively associated with Hb, ferritin, and RBC count [10]. In addition, potential misclassification of diabetes using HbA1c in diabetes persons with IDA may result in misdiagnosis [7]. However, HbA1c decreases significantly after treatment of HbA1c [20]. The mean HbA1C of IDA patients were statistically significantly higher than the non-anemic group [21]. Moreover, it was hypothesized that excessive iron load can damage the pancreatic β cells, which promotes the development of insulin resistance [22]. The hemoglobin molecule's quaternary structure changes in IDA and increases the glycosylation of globin in the presence of low iron levels. Furthermore, hemoglobin glycosylation is connected to microvascular problems in diabetic persons with IDA, which leads to diabetes complications [9].

It was proposed that the concentration of HbA1c in red blood cells tends to rise with cell aging and that the synthesis of glycated hemoglobin is irreversible. HbA1c levels are normal when blood glucose and red blood cell life span are both within normal ranges, but they decrease after iron therapy because red blood cell life span is reduced. However, in the case of chronic IDA, red blood cell synthesis will decrease, resulting in extended red blood cell survival in circulation. Eventually, this will result in higher HbA1c readings [23]. A similar finding was seen in a study conducted by Zhuang *et al*. [24], they found that IDA was correlated with increased HbA1c concentrations. Also, they noticed a statistically significant decrease in HbA1c with iron replacement therapy. These results could be explained by the fact that iron treatment led to normalized RBC survival which was prolonged with a decrease in malondialdehyde levels.

The findings of our study revealed that there is a direct positive relationship between HbA1c levels and ferritin. The findings also show an inverse relationship between HbA1c and transferrin. The fact that serum

ferritin is regarded as an acute-phase response measure. It rises when the body is subject to conditions like inflammation, which can impair insulin release and interfere with normal glucose metabolism. This could therefore result in a rise in HbA1c values [25]. Several studies have found results close to ours and found elevated serum ferritin levels in people with type 2 diabetes. They discovered that elevated serum ferritin levels in Western and Asian populations were linked to a higher risk of developing diabetes [19], [26]–[29]. Furthermore, Serum ferritin was shown to be considerably greater in diabetic patients than in controls and to rise significantly with increasing diabetes duration [30]. Also, Rajagopal *et al*. [31] supported our findings that patients with poorly managed diabetes had elevated serum ferritin levels. Moreover, in the study of the correlation of the HbA1c with IDA in 50 non-diabetic female patients in Mangaluru, India in 2022, the participants had decreased levels of Hb, MCV, and mean corpuscular hemoglobin concentration (MCHC). The results showed that there was a significant decrease in the mean value of HbA1c in those with severe anemia compared to those with moderate anemia. Therefore, it was concluded that there was a positive correlation between HbA1c with ferritin and hemoglobin and that it should be a consideration of iron status in the interpretation of the HbA1c concentrations in diabetes mellitus [6], [10]. The results showed that the absolute HbA1c level was significantly lower in the mild and moderate-severe anemia groups than in the non-anemic group and it was positively associated with Hb, ferritin, and RBC count [32].

4. CONCLUSION

HbA1c increases significantly as the severity of anemia worsens. Therefore, IDA must be corrected before any diagnostic or therapeutic decision is made based solely on the HbA1c level. The importance of this study lies in determining appropriate methods to adjust HbA1c in the setting of anemia that could improve diabetes monitoring and prevent complications. Furthermore, by demonstrating the mechanisms by which iron deficiency disrupts glucose homeostasis, it may help to manifest opportunities to optimize metabolic control through iron repletion.

The study's main strength is that the participants are adults of varying ages who are comparing two diabetes groups with non-diabetes groups. The study also takes into account the other relevant variables that may affect the study's results. The study's limitation is that we rely on a single biochemical analysis measurement. Furthermore, the findings of the study demonstrated that ferritin levels should be considered during therapy in diabetic patients who also have anemia to reduce HbA1c levels. Furthermore, because this is an observational study, no causality can be determined. To determine the relationship between HbA1c, ferritin, transferrin, and MCV, prospective and clinical studies are required.

REFERENCES

[1] A. Angelousi and E. Larger, "Anaemia, a common but often unrecognized risk in diabetic patients: a review," *Diabetes & Metabolism*, vol. 41, no. 1, pp. 18–27, 2015, doi: 10.1016/j.diabet.2014.06.001.

[2] B. M. A. Salma, F. Thekrallah, A. Qatawneh, H. Hasan, S. Shawaqfeh, and M. Al Tarawneh, "Effect of intermittent fasting on improving body composition and anthropometric measurements of women with polycystic ovarian syndrome," *Nutrición Clínica Y Dietética Hospitalari*, vol. 44, no. 2, pp. 122–129, 2024, doi: 10.12873/442abu.

[3] C. Bozkir, "Iron Deficiency Anemia and Diabetes Mellitus," *Interventions in Obesity & Diabetes*, vol. 3, no. 2, 2019, doi: 10.31031/iod.2019.03.000557.

[4] A. L. Christy, P. A. Manjrekar, R. P. Babu, A. Hegde, and M. S. Rukmini, "Influence of iron deficiency anemia on hemoglobin A1c levels in diabetic individuals with controlled plasma glucose levels," *Iranian Biomedical Journal*, vol. 18, no. 2, pp. 88–93, 2014, doi: 10.6091/ibj.1257.2014.

[5] C. J. Petry, "Iron supplementation in pregnancy and risk of gestational diabetes: a narrative review," *Nutrients*, vol. 14, no. 22, p. 4791, Nov 2022, doi: 10.3390/nu14224791.

[6] D. Janice *et al*., "Effect of iron deficiency anemia on glycated hemoglobin in non-diabetic women," *International Journal of Biochemistry and Molecular Biology*, vol. 13, no. 3, pp. 23–27, Jun. 2022.

[7] B. Aydın, S. Özçelik, T. P. Kilit, S. Eraslan, M. Çelik, and K. Onbaşı, "Relationship between glycosylated hemoglobin and iron deficiency anemia: A common but overlooked problem," *Primary Care Diabetes*, vol. 16, no. 2, pp. 312–317, Apr. 2022, doi: 10.1016/j.pcd.2022.01.002.

[8] S. Ç. Altuntaş, M. Evran, E. Gürkan, M. Sert, and T. Tetiker, "HbA1c level decreases in iron deficiency anemia," *Wiener klinische Wochenschrift*, vol. 133, no. 3–4, pp. 102–106, Feb. 2021, doi: 10.1007/s00508-020-01661-6.

[9] L. Kuang, W. Li, G. Xu, M. You, W. Wu, and C. Li, "Systematic review and meta-analysis: influence of iron deficiency anemia on blood glycosylated hemoglobin in diabetic patients," *Annals of Palliative Medicine*, vol. 10, no. 11, pp. 11705–11713, Nov. 2021, doi: 10.21037/apm-21-2944.

[10] I. A. Bindayel, "Influence of iron deficiency anemia on glycated hemoglobin levels in non-diabetic Saudi women," *Journal of International Medical Research*, vol. 49, no. 2, p. 300060521990157, Feb. 2021, doi: 10.1177/0300060521990157.

[11] A. T. Soliman, V. De Sanctis, M. Yassin, and N. Soliman, "Iron deficiency anemia and glucose metabolism," *Acta Biomedica*, vol. 88, no. 1, pp. 112–118, Apr. 2017, doi: 10.23750/abm.v88i1.6049.

[12] S. Sundararajan and H. Rabe, "Prevention of iron deficiency anemia in infants and toddlers," *Pediatric Research*, vol. 89, no. 1, pp. 63–73, Jan. 2021, doi: 10.1038/s41390-020-0907-5

[13] J. Barbieri *et al*., "Anemia in patients with type 2 diabetes mellitus," *Anemia*, vol. 2015, no. 1, p. 354737, 2015, doi: 10.1155/2015/354737.

[14] S.-R. Pasricha, J. Tye-Din, M. U. Muckenthaler, and D. W. Swinkels, "Iron deficiency," *The Lancet*, vol. 397, no. 10270, pp. 233–248, 2021, doi: 10.1016/S0140-6736(20)32594-0
[15] World Health Organization, "BMI classification. Global database on body mass index," WHO, 2004. Accessed on**:** December 11, 2024. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.
[16] S. Kalairajan, V. Durairaj, and K. M. Malathy, "A study on influence of iron deficiency anaemia over HbA1c levels," *International Journal of Advances in Medicine*, vol. 6, no. 4, p. 1095, Jul. 2019, doi: 10.18203/2349-3933.ijam20192586.
[17] J. Cotter, C. Baldaia, M. Ferreira, G. Macedo, and I. Pedroto, "Diagnosis and treatment of iron-deficiency anemia in gastrointestinal bleeding: A systematic review," *World Journal of Gastroenterology*, vol. 26, no. 45, pp. 7242–7257, Dec. 2020, doi: 10.3748/wjg.v26.i45.7242.
[18] A. Akdi *et al*., "Glycosylated hemoglobin a1c and lipoprotein(a) in patients presenting with premature acute coronary syndrome," *Angiology*, vol. 71, no. 8, p. 762, Sep. 2020, doi: 10.1177/0003319719897491.
[19] S. M. Attard *et al*., "Implications of iron deficiency/anemia on the classification of diabetes using HbA1c," *Nutrition & Diabetes*, vol. 5, no. 6, p. e166, Jun. 2015, doi: 10.1038/nutd.2015.16.
[20] C. Huth *et al*., "Biomarkers of iron metabolism are independently associated with impaired glucose metabolism and type 2 diabetes: the KORA F4 study," *European Journal of Endocrinology*, vol. 173, no. 5, pp. 643–653, Nov. 2015, doi: 10.1530/EJE-15-0631.
[21] L. Rajagopal, A. Sundaram, and Shivashekar, "Impact of iron deficiency anemia on glycated hemoglobin (HbA1c) levels in diabetics with controlled plasma glucose levels," *Annals of Pathology and Laboratory Medicine*, vol. 4, no. 2, pp. A148–A152, 2017, doi: 10.21276/apalm.1126.
[22] J. F. Silva, A. L. Pimentel, and J. L. Camargo, "Effect of iron deficiency anaemia on HbA1c levels depends on the degree of anaemia," *Clinical Biochemistry*, vol. 49, no. 1–2, pp. 117–120, Jan. 2016. doi: 10.1016/j.clinbiochem.2015.09.004
[23] J. C. Fernández-Cao, *et al*., "Soluble transferrin receptor and risk of type 2 diabetes in the obese and nonobese," *European Journal of Clinical Investigation*, vol. 47, no. 3, pp. 221–230, Mar. 2017, doi: 10.1111/eci.12725.
[24] T. Zhuang, H. Han, and Z. Yang, "Iron, oxidative stress and gestational diabetes," *Nutrients*, vol. 6, no. 9, pp. 3968–3980, 2014, doi: 10.3390/nu6093968.
[25] V. Arija *et al*., "Excess body iron and the risk of type 2 diabetes mellitus: a nested case-control in the PREDIMED (Prevention with Mediterranean Diet) study," *The British Journal of Nutrition*, vol. 112, no. 11, pp. 1896–1904, 2014, doi: 10.1017/S0007114514002852.
[26] X. Guo *et al*., "Associations between serum hepcidin, ferritin and Hb concentrations and type 2 diabetes risks in a Han Chinese population," *The British Journal of Nutrition*, vol. 110, no. 12, pp. 2180–2185, 2013, doi: 10.1017/S0007114513001827.
[27] C. H. Jung *et al*., "Elevated serum ferritin level is associated with the incident type 2 diabetes in healthy Korean men: a 4-year longitudinal study," *PLOS ONE*, vol. 8, no. 9, p. e75250, 2013, doi: 10.1371/journal.pone.0075250.
[28] S. Kim *et al*., "Incidental risk for diabetes according to serum ferritin concentration in Korean men," *Clinica Chimica Acta*, vol. 451, part. B, pp. 165–69, 2015, doi: 10.1016/j.cca.2015.09.024.
[29] C. Wittenbecher *et al*., "Amino acids, lipid metabolites, and ferritin as potential mediators linking red meat consumption to type 2 diabetes," *American Journal of Clinical Nutrition*, vol. 101, no. 6, pp. 1241–1250, 2015, doi: 10.3945/ajcn.114.099150.
[30] S. Raj and G. Rajan, "Correlation between elevated serum ferritin and HbA1c in type 2 diabetes mellitus," *International Journal of Research in Medical Sciences*, vol. 1, no. 1, pp. 12–15, 2013. doi: 10.5455/2320-6012.ijrms20130203.
[31] L. Rajagopal, S. Ganapathy, S. Arunachalam, V. Raja, and B. Ramraj, "Does iron deficiency anaemia and its severity influence HbA1C Level in non diabetics? an analysis of 150 cases," *Journal of Clinical and Diagnostic Research*, vol. 11, no. 2, pp. EC13–EC15, Feb. 2017. doi: 10.7860/JCDR/2017/25183.9464.
[32] M. Koga, H. Saito, M. Mukai, S. Matsumoto, and S. Kasayama, "Influence of iron metabolism indices on glycated haemoglobin but not glycated albumin levels in premenopausal women," *Acta Diabetologica*, vol. 47, Suppl. 1, pp. 65–69, 2010, doi: 10.1007/s00592-009-0123-6.

BIOGRAPHIES OF AUTHORS

Saida Fuad Shnaigat is an assistant professor in Human Nutrition and Dietetics, Department of Food and Nutrition Science, Jerash University, Jordan. Her research interests are focused on diet and cancer research, specifically breast cancer, nutrition and obesity, nutrition and diabetes type 2, role of nutrient factors in the incidence and treatment of nutrition-related disease, and food security. She can be contacted at email: s.shnaqat@jpu.edu.jo.

Baha'a M. Abu Salma is an assistant professor in Human Nutrition and Dietetics, Department of Food and Nutrition Science, Jerash University, Jordan. Her research interests focus on functional foods such as pectin and pullulan, human nutrition therapy, child and pregnant women nutrition, and the role of omega-3 in health. Vice president of Jordanian Food and Nutrition Society. Author of several international peer-reviewed publications about human nutrition. She can be contacted at email: bahaabusalma@gmail.com or b.abusalma@jpu.edu.jo.