RESEARCH ARTICLE
Eurasian J Bio Chem Sci, 8(1):33-39, 2025
https://doi.org/10.46239/ejbcs.1684314

EJBCS

Eurasian Journal of Biological and Chemical Sciences

Journal homepage: www.dergipark.org.tr/ejbcs

Niacin deficiency and hormonal imbalance as emerging biochemical markers in women with type 1 and type 2 diabetes mellitus

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Received : 26/04/2025
Accepted : 22/06/2025

To Cite / Atıf için: Alaiesh HIB, Adem Ş 2025. Niacin deficiency and hormonal imbalance as emerging biochemical markers in women with type 1 and type 2 diabetes mellitus. Eurasian J Bio Chem Sci, 8(1):33-39 https://doi.org/10.46239/ejbcs.1684314

Abstract: Diabetes mellitus, particularly Type 2 (T2DM), is increasingly common among young adults and is associated with metabolic syndrome and endocrine dysfunction. Niacin (vitamin B3), essential for lipid and energy metabolism, may serve as a diagnostic marker for diabetic complications. This study compared niacin levels, steroid hormone profiles, and hematological markers in women with Type 1 (T1DM) and Type 2 diabetes versus non-diabetic controls. A total of 180 women aged ≥20 were evenly divided into T1DM, T2DM, and control groups. Blood samples were collected to measure niacin, estradiol (E2), follicle-stimulating hormone (FSH), luteinizing hormone (LH), red blood cells (RBC), hemoglobin (Hb), and glycated hemoglobin (HbA1C). Statistical analysis included mean comparison and Pearson correlation. Both diabetic groups exhibited significantly lower niacin levels (T1DM: 2.50 µg/L; T2DM: 2.61 µg/L) compared to controls (3.75 µg/L). Elevated E2 and reduced FSH and LH levels were observed in diabetic women, suggesting endocrine disruption. Additionally, RBC and Hb levels were lower (T1DM: 10.85 g/dL; T2DM: 11.70 g/dL) compared to controls (14.32 g/dL), while HbA1C was higher (T1DM: 6.76%; T2DM: 5.83%; controls: 5.25%). Significant negative correlations were found for RBC, Hb, FSH, LH, and niacin, while positive correlations were found for E2 and HbA1C with diabetic status. These results indicate that diabetes in women is associated with systemic biochemical anomalies, including niacin deficiency, impaired hematopoiesis, and hormonal dysregulation. The findings emphasize the importance of holistic treatment approaches considering metabolic, nutritional, and hormonal factors in female diabetes patients.

Keywords: Diabetes Mellitus, Niacin, Steroid Hormones, Women, Hemoglobin, HbA1C.

Tip 1 ve Tip 2 Diyabetli Kadınlarda Yeni Ortaya Çıkan Biyokimyasal Belirteçler Olarak Niasin Eksikliği ve Hormonal Dengesizlik

Özet: Diabetes mellitus, özellikle Tip 2 Diyabet (T2DM), genç yetişkinler arasında giderek daha yaygın hale gelmekte olup metabolik sendrom ve endokrin disfonksiyonla ilişkilidir. Lipid ve enerji metabolizması için hayati öneme sahip bir besin öğesi olan niasin (B3 vitamini), diyabetik komplikasyonların tanısında potansiyel bir biyobelirteç olarak kullanılabilir. Bu çalışma, Tip 1 (T1DM) ve Tip 2 diyabetli kadınlar ile diyabetik olmayan kontrol grupları arasında niasin düzeylerini, steroid hormon profillerini ve hematolojik belirteçleri karşılaştırmıştır. Çalışmaya yaşları ≥20 olan toplam 180 kadın dahil edilmiş ve katılımcılar eşit şekilde T1DM, T2DM ve kontrol gruplarına ayrılmıştır. Kan örnekleri alınarak niasin, östradiol (E2), folikül uyarıcı hormon (FSH), luteinize edici hormon (LH), kırmızı kan hücreleri (RBC), hemoglobin (Hb) ve glikozile hemoglobin (HbA1C) düzeyleri ölçülmüştür. İstatistiksel analizler ortalama karşılaştırması ve Pearson korelasyon testi ile gerçekleştirilmiştir. Her iki diyabet grubunda da kontrol grubuna kıyasla anlamlı şekilde daha düşük niasin düzeyleri (T1DM: 2,50 µg/L; T2DM: 2,61 µg/L; kontrol: 3,75 µg/L) gözlemlenmiştir. Diyabetli kadınlarda artmış E2 ve azalmış FSH ile LH düzeyleri saptanmış, bu durum endokrin bozulmayı işaret etmiştir. Ayrıca, RBC ve Hb düzeyleri de diyabetli gruplarda daha düşük (T1DM: 10,85 g/dL; T2DM: 11,70 g/dL; kontrol: 14,32 g/dL) bulunmuş, HbA1C düzeylerinde ise artış (T1DM: %6,76; T2DM: %5,83; kontrol: %5,25) saptanmıştır. Diyabetik durumla RBC, Hb, FSH, LH ve niasin için anlamlı negatif korelasyonlar; E2 ve HbA1C için ise pozitif korelasyonlar belirlenmiştir. Bu sonuçlar, kadınlarda diyabetin, niasin eksikliği, hematopoez bozukluğu ve hormonal düzensizlik gibi sistemik biyokimyasal anormalliklerle ilişkili olduğunu göstermektedir. Bulgular, kadın diyabet hastalarının tedavisinde metabolik, beslenme ve hormonal faktörleri birlikte dikkate alan bütüncül yaklaşımların önemini vurgulamaktadır.

Anahtar Kelimeler: Diyabetes Mellitus, Niasin, Steroid Hormonlar, Kadınlar, Hemoglobin, HbA1C

1. Introduction

Type 1 diabetes mellitus (T1DM) and type 2 diabetes mellitus (T2DM) are the two primary forms of the metabolic disorder known as diabetes mellitus, which is characterized by chronic hyperglycemia. T1DM is an autoimmune condition that results in a lifelong deficiency in insulin production, whereas T2DM is primarily defined by insulin resistance often accompanied by a relative decline in insulin secretion (Singh et al. 2024).

T2DM has become a major public health concern globally, with its incidence rising steadily since the 1980s (Cho et al. 2018). While it was traditionally seen in middle-aged and older individuals, recent years have seen a marked increase in its prevalence among younger adults (under 40), adolescents, and even children (Viner et al. 2017). This trend is largely attributed to the global rise in obesity rates. Notably, T2DM began emerging among young populations such as the Pima Indians in the United States and First Nations communities in Canada in the 1980s and 1990s (Magliano et al. 2020).

Both T1DM and T2DM are associated with significant morbidity and mortality due to complications affecting nearly all organ systems. Common macrovascular and microvascular complications include cardiovascular disease (CVD), retinopathy, neuropathy, and chronic kidney disease (Harding et al. 2019). More recently, non-alcoholic fatty liver disease, mental health disorders (e.g., depression), cancer, cognitive impairment, infections, and disability have also been identified as diabetes-related conditions.

Young individuals with T2DM often experience a more rapid decline in β-cell function and face a higher risk of complications compared to those with T1DM, suggesting a more aggressive disease phenotype (Viner et al. 2017). However, whether early-onset T2DM leads to worse outcomes than late-onset T2DM remains uncertain.

Metabolic syndrome (MetSy), characterized by central obesity, hyperglycemia, hypertension, elevated triglycerides, and low high-density lipoprotein (HDL) levels, is present in 70–80% of diabetes cases (Asghar et al. 2023). It is associated with a threefold increased risk of CVD, various microvascular complications, and premature death (Ford 2005). MetSy is increasingly recognized as a common comorbidity in both T1DM and T2DM worldwide. Although its exact etiology remains unclear, insulin resistance and central obesity are considered major contributing factors. Other potential contributors include aging, genetic predisposition, chronic hyperglycemia, inflammation, hormonal imbalances, dietary changes, and physical inactivity, with variability observed across different ethnic groups (Gui et al. 2017; Belete et al. 2021).

Atherogenic dyslipidemia, marked by high triglycerides and low HDL, is closely linked to increased adiposity and sedentary behavior, which are also correlated with rising T2DM incidence (Stanaway et al. 2018). Despite the widespread use of statins to reduce cardiovascular risk and improve lipid profiles, they have limited effects on triglycerides and HDL levels (Fruchart et al. 2010). This limitation underscores the need for additional strategies to manage lipid abnormalities in diabetic patients.

One such strategy is niacin (vitamin B3) supplementation, which is known to reduce low-density lipoprotein (LDL), plasma triglycerides (TG), and increase HDL levels (Malik and Kashyap 2003). Previous studies have suggested that niacin may reverse coronary atherosclerosis and reduce cardiac mortality (Duggal et al. 2010), though its role in statin-treated patients remains debated (Boden et al. 2011). Given the high prevalence of dyslipidemia among individuals with T2DM, further investigation into the impact of niacin supplementation in this group is warranted (Xiang et al. 2020).

Steroid hormones, which exert diverse physiological effects by binding to specific nuclear receptors, are synthesized from cholesterol through enzymatic pathways. Over the past three decades, research in enzyme kinetics and precursor-product relationships has established that numerous enzymes are responsible for converting cholesterol into active steroid hormones. Advances in protein chemistry and molecular biology have significantly deepened our understanding of these biosynthetic mechanisms (D'Andrea et al. 2019).

This study aims to compare women with type 1 and type 2 diabetes to healthy controls in order to investigate the impact of diabetes on niacin levels, steroid hormone profiles (E2, FSH, LH), and hematological parameters (RBC, Hb, HbA1C). It is hypothesized that systemic metabolic and endocrine dysregulation in diabetic patients leads to marked reductions in niacin and hematological indices, as well as significant disruptions in reproductive hormone levels regardless of diabetes type.

The original contribution of this study lies in its comprehensive approach, which aims to uncover interconnected disruptions in female diabetic patients that are often overlooked when biomarkers are assessed in isolation. By identifying specific patterns of dysregulation across multiple physiological systems, this work provides a more complete understanding of how diabetes affects women's health. The findings are expected to inform more holistic diagnostic frameworks and support the development of targeted interventions that address the multifactorial nature of diabetes in women.

The rest of study is as follows: Section 2 details the methodology; Section 3 presents the main findings, including reduced levels of niacin, FSH, LH, RBC, and hemoglobin, and elevated E2 and HbA1C in diabetic women; Section 4 offers a critical interpretation of these findings in the context of current literature, examining factors such as insulin resistance, endocrine feedback disruptions, oxidative stress, and altered erythropoiesis; Section 5 concludes with an emphasis on the systemic effects of diabetes on women's hormonal and hematological health, and underscores the importance of integrated treatment approaches addressing both metabolic and endocrine dysfunctions.

2. Materials and Method

2.1. Study groups and blood samples

In this study, 180 samples, consist of diabetes mellitus disease patients (Group A: Consists of 60 women with type 1 diabetes mellitus and group B: Consists of 60 women with type 2 diabetes mellitus) between the age of 20 and above. Group C: Consists of 60 women without diabetes mellitus as control group. The study included collecting blood samples from 180 women who attended government hospitals and health centers and who suffered from metabolic syndrome, by taking a blood amount of 5 mL or more using sterile plastic syringes, and then keeping the samples in sterile plastic containers until the required laboratory tests were performed. As illustrated in Figure 1, the participants were evenly divided among the three groups.

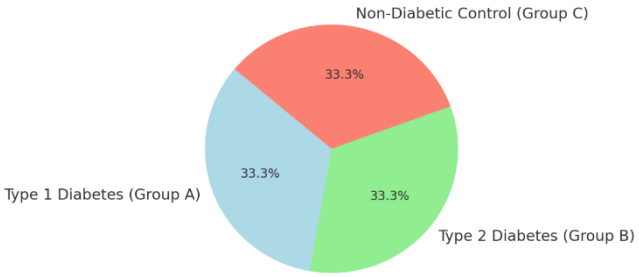

Fig. 1 Proportional distribution of study participants across three groups

2.2. Biochemical analysis

Serum niacin, estradiol (E2), follicle-stimulating hormone (FSH), luteinizing hormone (LH), RBC count, hemoglobin (Hb) and glycated hemoglobin (HbA1C) levels were measured using biochemical investigations. A spectrophotometric assay that was modified from DDQ (dichloro-5,6-dicyano-p-benzoquinone) method was used to measure niacin concentrations. The concentrations of estradiol, FSH and LH were determined by following the instructions provided by the manufacturer of standardized ELISA kits (Bioassay Technology Laboratory, Shanghai, China). An automated hematology analyzer such as the Sysmex XP-300 used to determine hematological parameters, including RBC and Hb. High-performance liquid chromatography (HPLC) with a certified NGSP-traceable assay was used to measure HbA1C levels. With the use of internal quality controls, every analytical batch was run in compliance with the established clinical laboratory standards for all measurements.

2.3 Statistical analysis

The statistical program SPSS 22.0 was used to analyze the data statistically and extract the average values, standard deviation, and standard deviation, in addition to finding the Pearson correlation between metabolic syndrome and some of the criteria studied. For correlation analysis, the study groups were coded as follows: 0 = healthy control, 1 = type 1 diabetes, and 2 = type 2 diabetes. This numeric coding allowed for assessment of linear relationships using Pearson's correlation coefficient.

3. Results

3.1 Niacin concentrations

The average niacin values for the three groups of women tested varied significantly, as shown in Table 1. However, the two groups of women with type 1 and type 2 diabetes demonstrated a notable decrease in niacin levels, reaching 2.50 and 2.61 µg/L, respectively while the group of women without diabetes had a niacin percentage of 3.75 µg/L.

Table 1 Niacin level of women of studied groups

Group	Niacin (µg/L)
Control	3.75±2.38
T1DM	2.51±2.10
T2DM	2.61±2.32
Total	2.96±2.33

Figure 2 shows the Niacin level of women of studied groups

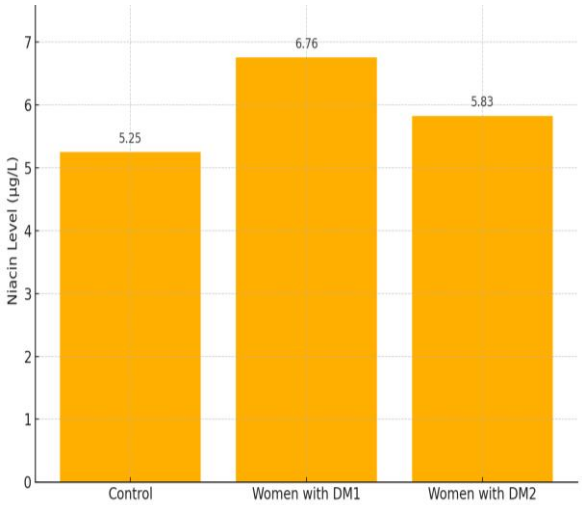

Fig. 2 Niacin level of women of studied groups

Women with type 1 and type 2 diabetes have significantly lower niacin levels than non-diabetic controls which can be ascribed to a number of physiological and metabolic variables usually linked with diabetes mellitus. One major cause is that diabetics have higher metabolic demand and oxidative stress which can lead to a deficiency in important micronutrients like niacin. Chronic hyperglycemia and systemic inflammation, which are hallmarks of diabetes have been shown to increase reactive oxygen species (ROS) levels raising the body's need for antioxidant and coenzyme molecules such as niacin which is essential for redox equilibrium and energy metabolism.

Insulin resistance and decreased glucose utilization in type 2 diabetes may also affect nutritional absorption and metabolism, thereby lowering niacin bioavailability or cellular uptake. In type 1 diabetes autoimmune dysfunctions and impaired nutrition metabolism may also contribute to reduced levels. Niacin is also involved in lipid metabolism and DNA repair, and its deficiency in diabetic women may be due to increased use in an attempt to compensate for

abnormal metabolic states. Furthermore, dietary choices in diabetics particularly carbohydrate restriction or poor nutritional intake may impair dietary niacin ingestion.

3.2 Steroid hormone profiles

The levels of estradiol (E2), follicle-stimulating hormone (FSH), and luteinizing hormone (LH) were compared among the three groups to determine the effect of diabetes on female reproductive hormones. Table 2 and Figures 3 and 4 show significant hormonal variations across the three study groups. Women with type 1 and type 2 diabetes had significantly higher estradiol (E2) levels, measuring 94.33 pg/mL and 107.40 pg/mL, respectively, compared to 61.48 pg/mL in non-diabetic women. In contrast, diabetic women had considerably lower levels of follicle-stimulating hormone (FSH), with values of 4.03 mIU/mL (type 1) and 4.32 mLU/mL (type 2), compared to 4.89 mIU/mL in the control group. Similarly, diabetic groups had lower luteinizing hormone (LH) levels (5.56 IU/mL and 4.15 IU/mlL for type 1 and type 2 diabetes, respectively) compared to non-diabetic women who had 7.60 IU/mL.

Table 2 Steroid hormone level of women of studied groups

Group	Estradiol (pg/mL)	FSH (mIU/mL)	LH (IU/mL)
Control	61.48±27.65	4.89±1.83	7.61±1.33
T1DM	94.33±68.43	4.03±0.83	5.56±1.42
T2DM	107.40±81.54	4.32±0.71	4.16±1.18
Total	87.74±66.04	4.42±1.28	5.78±1.93

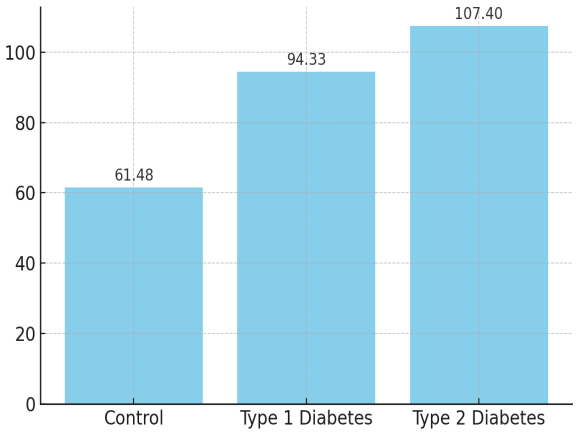

Fig. 3 Estradiol levels across study groups

The hormonal findings in this study elevated estradiol (E2) levels in diabetic women as well as lower follicle-stimulating hormone (FSH) and luteinizing hormone (LH) levels can be related to diabetes's disruptive effects on the hypothalamic-pituitary-gonadal (HPG) axis. In women with diabetes, particularly type 2, insulin resistance and compensatory hyperinsulinemia increase androgen synthesis which is then converted to estradiol by increased aromatase activity in adipose tissue. Elevated estradiol levels then exert negative feedback on the hypothalamus and pituitary gland, inhibiting GnRH release and, as a result, reducing FSH and LH output. Furthermore, prolonged hyperglycemia and metabolic inflammation associated with diabetes might affect neuroendocrine regulation and hormone metabolism, exacerbating the imbalance. These hormonal disturbances reflect a broader dysregulation of reproductive function in diabetic women, which may explain menstrual irregularities, anovulation, and decreased fertility in this population.

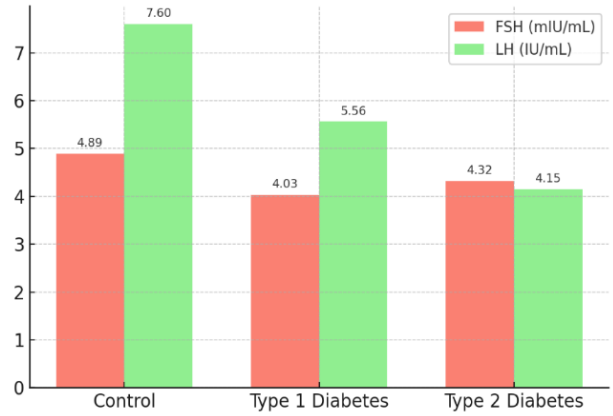

Fig. 4 FSH and LH levels across study groups

Recent evidence indicates that niacin deficiency may affect the hypothalamic-pituitary-gonadal (HPG) axis via multiple biochemical pathways. Niacin is an essential precursor of nicotinamide adenine dinucleotide (NAD^+), which governs various cellular processes, including oxidative metabolism, mitochondrial function, and gene expression through sirtuins (SIRT) and poly (ADP-ribose) polymerases (PARPs). SIRT1, NAD^+-dependent enzyme has been demonstrated to influence secretion of gonadotropin-releasing hormone (GnRH) in hypothalamus and to regulate pituitary's responsiveness to GnRH stimulation. Research on animals demonstrates that NAD^+ depletion disrupts reproductive axis signaling and fertility by diminishing expression of GnRH and gonadotropin subunits. Furthermore, niacin deficiency has been associated with increased oxidative stress and inflammatory cytokines, which have the potential to disrupt endocrine signaling within the HPG axis, particularly in metabolically impaired conditions like diabetes. These results indicate that the hormonal imbalances observed in diabetic women, specifically the elevated estradiol and diminished FSH and LH levels, may be partially due to the disruption of central and peripheral reproductive regulation induced by niacin.

3.3 Hematological parameters

To assess the hematological impact of diabetes, red blood cell (RBC) count, hemoglobin (Hb), and glycated hemoglobin (HbA1c) levels were analyzed across the three study groups. As shown in Table 3 and Figure 5, there were significant differences in RBC counts among the groups. Women with type 1 and type 2 diabetes exhibited reduced RBC values of 4.53 × 106/L and 5.10 × 106/L, respectively, compared to 5.35 × 106/L in non-diabetic women.

Similarly, hemoglobin levels were significantly lower in diabetic participants, with type 1 and type 2 groups recording averages of 10.85 g/dL and 11.70 g/dL, respectively, while the control group reached 14.32 g/dL. In contrast, HbA1c levels were significantly elevated in the diabetic groups. Women with type 1 and type 2 diabetes recorded HbA1c values of 6.76% and 5.83%, respectively, compared to 5.25% in the healthy control group.

Table 3 RBC, hemoglobin and HbA1C count of women of studied groups

Group	RBC ($\times 10^6/\mu L$)	Hemoglobin (g/dL)	HbA1C (%)
Control	5.35±0.12	14.32±0.70	5.25±0.25
T1DM	4.53±0.20	10.85±0.33	6.76±0.57
T2DM	5.11±0.08	11.71±0.16	5.83±0.17
Total	5.00±0.37	12.29±1.55	5.95±0.72

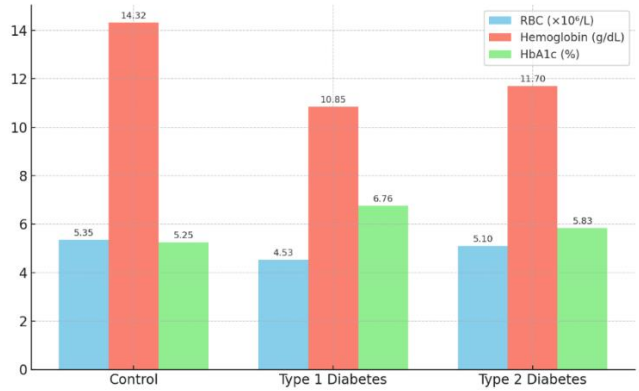

Fig. 5 RBC, hemoglobin and HbA1C values of women and studied groups

3.4 Correlation analysis

A strong negative correlation was observed between RBC count and the studied groups, with a correlation coefficient of -0.268 at the 0.01 significance level. Similarly, hemoglobin values in women of reproductive age showed a strong negative correlation with the studied groups, recording a coefficient of -0.692 at the 0.01 level. Conversely, the HbA1C values exhibited a strong positive correlation with the studied groups, reaching 0.328 at the 0.01 significance level. In addition, a strong negative correlation was identified between niacin levels and the studied groups ($r = -0.201$, $p < 0.01$), while estradiol (E2) levels showed a strong positive correlation ($r = 0.285$, $p < 0.01$). Furthermore, the analysis revealed a significant negative correlation between FSH levels and the studied groups, with a coefficient of -0.183 at the 0.05 significance level. Finally, the LH levels were also found to have a strong negative correlation with the studied groups, recording a coefficient of -0.732 at the 0.01 level. The results presented in Table 4 and Figure 6 indicate several statistically significant correlations identified through Pearson correlation analysis.

The findings demonstrate that diabetes mellitus has considerable impact on women's hematological and hormonal profiles. The negative correlation between RBC count and hemoglobin levels among the studied groups suggests that diabetic women have lower red blood cell counts and hemoglobin concentrations which are most likely caused by chronic hyperglycemia, oxidative stress, inflammation or diabetic nephropathy all of which can impair erythropoiesis and promote anemia. In contrast, HbA1C levels were positively linked with the examined groups, indicating poor long-term glycemic management in diabetes patients. Niacin levels exhibited a negative correlation, possibly due to increased metabolic demand and oxidative stress, which deplete vitamin B3 levels. Estradiol (E2) levels were also positively connected with diabetes, which could be attributed to hormonal imbalances, insulin resistance, or obesity-related aromatization. In contrast, follicle-stimulating hormone (FSH) and luteinizing hormone (LH) levels were inversely linked with diabetes groups indicating hypothalamic-pituitary-gonadal axis suppression possibly due to higher estrogen feedback or metabolic disturbance. These connections underscore the systemic physiological changes caused by diabetes, which influence oxygen transport, food metabolism and reproductive endocrine function in women.

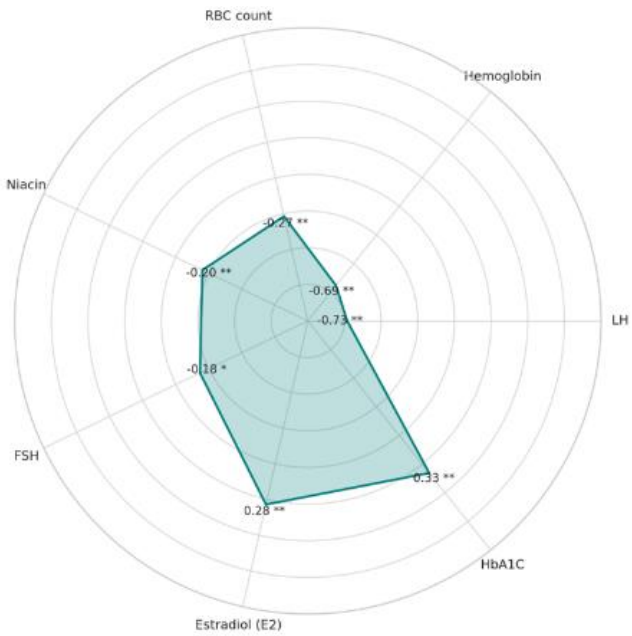

Fig. 6 Correlation patterns of biomarkers with study groups

4. Discussion

In women with diabetes mellitus, this study reveals a cascade of biochemical abnormalities, including niacin deficiency, steroid hormone imbalances and changed hemostatic markers. This study adds to and supports what is already known about the pathophysiology of metabolic syndrome and diabetes.

The decrease in serum niacin levels found in diabetic women can be explained by factors such as elevated metabolic demand, oxidative stress and impaired nutrient absorption or utilization. Redox reactions, DNA repair and lipid metabolism are all heavily reliant on niacin which is also required for NAD/NADP biosynthesis. Results showing a substantial inverse association between dietary niacin consumption and diabetes risk (Jiang et al. 2023) corroborate the idea that niacin depletion is worsened by chronic hyperglycemia and elevated reactive oxygen species in diabetes. In addition, there is ongoing debate about effectiveness of niacin supplementation in hyperglycemic populations although it has shown promise in improving lipid profiles and reducing cardiovascular risk (Duggal et al. 2010; Boden et al. 2011).

Disruption of the hypothalamic-pituitary-gonadal axis manifests as steroid hormone dysregulation, which is characterized by increased estradiol and decreased FSH/LH levels. Adipose tissue aromatase activity may be stimulated by hyperinsulinemia in type 2 diabetes, leading to the conversion of androgens to estrogens. This process then has a negative effect on gonadotropin secretion (Maric et al. 2010; Alemany 2021). Previous research has shown that diabetic women have lower gonadotropin levels and higher E2, which can lead to menstrual irregularities and reduced fertility (Natah et al. 2013; Bertone-Johnson et al. 2017). The endocrine effects of metabolic dysfunction, especially in women, are reflected in these hormonal changes.

Consistent with data linking diabetes to impaired erythropoiesis and anemia, the hematological changes noted include a decreased red blood cell count and hemoglobin concentration (Ebrahim et al. 2022). Diabetes may decrease erythrocyte survival and hemoglobin synthesis due to chronic inflammation, kidney dysfunction, and oxidative damage to red blood cells (Alamri et al. 2019). A long-term glycemic imbalance is major cause of vascular and hematological complications and elevated HbA1C levels further confirm this (Şener et al. 2023).

Taken as a whole, these results highlight how diabetes affects the entire body spanning the metabolic, dietary, endocrine and hematologic systems. Patient outcomes, particularly for women with diabetes may be improved by addressing these multidimensional changes through integrated care, which includes nutritional support (such as niacin supplementation), hormonal monitoring, and anemia management.

Although thorough, this study does have a few caveats. Diabetes and the biochemical variations observed cannot be causally interpreted due to the cross-sectional design. It is possible that unrecorded supplementation and food consumption affected serum niacin levels. Possible effects on FSH, LH, and estradiol levels were due to the lack of adjustment for menstrual cycle phases in the hormonal levels. Additional limitations that limit generalizability include the sample's lack of male participants and its geographical limitation to a single region. The results should be further validated and expanded upon in future studies by using interventional or longitudinal designs including dietary assessments and increasing the demographic scope.

Table 4 Pearson correlation analysis between study groups and selected biochemical and hematological parameters in women

Parameter	Pearson Correlation (r)	Significance (p-value)	Significance Level
RBC count	-0.268 **	0.000	**(p<0.01)
Hemoglobin	-0.692**	0.000	** (p<0.01)
HbA1C	0.328**	0.000	** (p<0.01)
Niacin	-0.201**	0.007	**(p<0.01)
Estradiol (E2)	0.285**	0.000	**(p<0.01)
FSH	-0.183*	0.014	* (p<0.05)
LH	-0.732**	0.000	** (p<0.01)

*Study groups were coded as 0 = healthy control, 1 = type 1 diabetes, and 2 = type 2 diabetes.

The results revealed several statistically significant associations. Hemoglobin ($r = -0.692$, $p < 0.01$) and LH ($r = -0.732$, $p < 0.01$) exhibited strong negative correlations with diabetes status, indicating marked reductions in these parameters among diabetic women. RBC count ($r = -0.268$, $p < 0.01$), niacin ($r = -0.201$, $p < 0.01$), and FSH ($r = -0.183$, $p < 0.05$) also showed negative correlations, suggesting declining levels with increasing severity of diabetes. Conversely, HbA1C ($r = 0.328$, $p < 0.01$) and estradiol (E2; $r = 0.285$, $p < 0.01$) were positively correlated with diabetes, reflecting elevated levels in diabetic patients.

These findings support the hypothesis that systemic metabolic and endocrine dysregulation occurs in women with both type 1 and type 2 diabetes. Importantly, the integrated correlation pattern observed across nutritional, hormonal, and hematological domains underscores the study's original contribution: revealing the complex, multifactorial impact of diabetes on women's health through simultaneous biomarker evaluation.

5. Conclusion

According to this study, significant biochemical and hematological changes such as reduced niacin levels, disrupted steroid hormone profiles, impaired red blood cell and hemoglobin indices are observed in women with type 1 and type 2 diabetes. These irregularities demonstrate how diabetes affects person's nutritional, hormonal, and hemostatic health on a systemic level. The importance of closely monitoring metabolic and reproductive health in women with diabetes is underscored by niacin deficiency and hormonal imbalances like increased estradiol levels with decreased FSH and LH. It is crucial to maintain effective glycemic control due to observed hematological disruptions and elevated HbA1C levels. These results lend

credence to the idea that metabolic, hormonal and nutritional pathway targeted integrated diagnostic and therapeutic strategies could be useful in bettering disease management and results for female diabetic populations. Longitudinal studies should be main emphasis of future investigations to prove causal links between diabetes and noted hormonal and biochemical changes. Furthermore, investigated should be the therapeutic benefits of hormonal control in diabetic populations and focused niacin supplements. Generalizability would be improved by extending the research to include male subjects and different demographic groups. Furthermore, including dietary assessments and analyzing phases of menstrual cycle could help to grasp nutritional and endocrine dynamics in diabetes in more whole sense. Combining omics techniques like transcriptomics and metabolomics find new biomarkers and therapeutic targets for individualized diabetes control.

Authors' contributions: Both authors contributed equally to the conception, design, and execution of the study titled. The first author was responsible for data collection, analysis, and drafting of the manuscript. The second author contributed to data interpretation, performed critical revisions, and finalized the manuscript for submission. Both authors reviewed and approved the final version of the manuscript.

Conflict of interest disclosure

The authors declare that there is no conflict of interest regarding the publication of this article.

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